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THE MEEKER WELL AND OTHER PHENOMENA IN THE VICINITY OF THE MEEKER DOME, RIO BLANCO COUNTY, COLORADO - A SUMMARY REPORT ON THE FEASIBILITY OF CONTROL OF SEEPAGE OF SALINE GROUND WATER

ENVIRONMENTAL PROTECTION AGENCY

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The occurrence of saline seeps in the vicinity of the Meeker Dome, near Meeker, Colorado in 1970 caused concern, as expressed by the State of Colorado and landowners. Of special concern was the fact that the seepage occurred less than two years after the plugging of the so-called "Meeker Well" and the Kritsas 1 and 2 wells would correct the problems caused by seepage and whether land-restoration (to agricultural productivity) methods were available. This report presents the water chemistry and aerial infrared imagery obtained by EPA to assist in the clarification.

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ABSTRACT

The occurrence of saline seeps in the vicinity of the Meeker Dome, near Meeker, Colorado in 1970 caused concern, as expressed by the State of Colorado and landowners. Of special concern was the fact that the seepage occurred less than two years after the plugging of the so-called "Meeker Well" and the Kritsas #1 and #2 wells. Questions arose, obviously, as to whether "replugging of wells would correct the problems caused by seepage and whether land-restoration (to agricultural productivity) methods were available. The Environmental Protection Agency was asked to take the lead in developing answers to the questions.

This report draws upon volunteer efforts by representatives of the State Water Conservation Board, the U.S. Geological Survey, the Bureau of Reclamation, and EPA. The significant conclusion is that the seepage of saline ground water to the ground surface appears to be the surface exhibition of a return of the Meeker Dome area to pre-drilling hydrologic equilibrium. The equilibrium is a function of saline water under pressure at depth and natural fractures which allow this water to reach the ground surface. While all of the wells in the area, including a brand new dry hole, may or can serve to connect deep aquifers with shallow aquifers we cannot substantiate this possibility with sufficient certainty to permit endorsement of any "replugging" efforts.

Land-restoration methods for a plot of irrigated farmland were elimintated as too complex. Restoration of access to an irrigation ditch appears feasible. Speculation as to the possibility that seepage into the irrigated land can be reduced through the use of upslope drains still exists.

Salinity measurements along the White River showed increases of total dissolved solids (a gain of 89 tons per day), sodium (21 tons per day), chloride (29 tons per day), and sulphate (24 tons per day). These increases appear to be about one-half of the increases in the same parameters measured prior to plugging the "Meeker Well."

Recommendations include those related to continued monitoring to insure that degradation of the White River may be forestalled.

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INTRODUCTION

On September 1, 1971, representatives of the Environmental Protection Agency accompanied representatives of the Bureau of Reclamation on a brief inspection of four areas of ground water seepage occurring east of Meeker, Colorado, near the White River. Subsequently, interest in and concern about the seepage increased to the point where, on June 15, 1972, the interested parties met in Meeker to agree upon a course of action that might resolve questions regarding the need to replug the so-called "Meeker Well" and the possibilities of controlling the ground water seepage. At that meeting, it was decided that EPA would serve as a lead agency in the collection of field data that were necessary, in turn, to clarify the hydrologic situation in the vicinity of the Meeker Well. This report presents the water chemistry and aerial infrared imagery obtained by EPA to assist in the clarification. This report also draws upon efforts of the Colorado Water Conservation Board, the U.S. Bureau of Reclamation, and the U.S. Geological Survey in an effort to present a current evaluation of the hydrologic system of the Meeker Dome.

BACKGROUND

The area of the Meeker Dome and areas of ground water seepage are portrayed in Figure 1. With the assistance of reports from Carter Hutchinson and Gene Hampton, a chronological summary of the pertinent events taking place in this area is contained in Table 1.

The "Meeker Well" was reentered and then grouted in August of 1968. Prior to the sealing, water quality data had been collected from upstream and downstream locations to evaluate the impact of the discharge from the flowing well on water quality. Along a 25 kilometer reach of the White River, which received the discharge from the well, the river gained an average 55 tons per day (tpd) of sodium, 65 tpd of chloride, 80 tpd of sulphate, and 280 tpd of dissolved solids prior to plugging. Calculations showed the Mecker Well effluent equalled about 87 percent, 108 percent, 32 percent, and 54 percent of these increases, respectively.

The well was plugged in August, 1968 under Specifications No. 400C-381 of a Small Business Contract administered by the Bureau of Reclamation. To achieve the plugging, the Meeker Well was first redrilled to 294 meters (with a concurrent increase in water discharge from the original 3 cfs to about 9 cfs). With much trouble, packers were sequentially set a 166 meters and 59 meters and the well was cemented shut. The plugging resulted in the cessation of surface flow and in a decrease in salts entering the White River. The decrease amounted to 44 tpd (tons per day) of sodium, 57 tpd of chloride, 37 tpd of sulphate, and 68 tpd of dissolved solids or

FIGURE 1

LOCATION MAP SHOWING AREAS OF LOCALIZED SEEPAGE

TABLE 1

CHRONOLOGICAL SUMMARY OF REPORTED EVENTS
IN THE VICINITY OF THE MEEKER DOME

1. ~1881 - Warm salt springs along the White River between Sections 20 and 29 (T1N, R93W) reportedly used for bathing by the Indians. Farming in southeast quarter of Section 20 reportedly difficult "because of the black shale."

2. 1915 - "Meeker Well" drilled to a depth of 560 meters by cable tool on the George Russell property. The oil test hole encountered warm, mineralized water. Some question still exists as to (1) whether another well was drilled at about the same location a few years later and plugged and (2) whether the "Meeker Well" was cased. (No casing was found during the reentry operation. Location: NW-1/4 Section 29 (T1N, R93W).

3. 1917-20 - Marland Oil Company well drilled in NE-1/4 NE-1/4 SW-1/4 Section 20 (T1N, R93W). Encountered warm, mineralized water with a head of about 1.5 meters above surface casing.

4. ca. 1927 - Local ranchers constructed dam downstream of Marland well to impound discharge.

5. 1945 - Scott well drilled, center NE-1/4, SW-1/4 Section 20 (T1N, R93W); later plugged; date of plugging not known but suspected to be in 1945.

6. 1957-60 - Kritsas #1 and #2 wells drilled by cable tool:
   #1 - NW-1/4 SE-1/4, SE-1/4, Section 8 (T1S. R93W).
   #2 - SW-1/4, Section 17 (T1N, R93W).

7. 1955-57 James well drilled, center SE-1/4, Section 29 (T1N, R93W). Plugged '57

8. 1967-8 - The "Meeker Well" was "rediscovered." On May 9, 1968, the well was discharging 3-cfs of brackish water with a concentration of 19,200 mg/l of dissolved solids. The discharge was estimated to add 57,000 tons of dissolved solids per year to the White River. In November 1967, the Federal Water Pollution Control Administration made funds available for Water Quality Research-Demonstration Projects and requested that the Bureau of Reclamation select pilot projects to test and demonstrate methods designed to reduce the salinity load in the Colorado River system. The plugging of two wells, one of which was the "Meeker Well," was selected.

9. July-Aug 1968 - With the concurrence of the Colorado State Engineer's Office, the Bureau of Reclamation contracted to cease the surface flow at the well head. The well was plugged from somewhere below 166 meters to the surface and measurable or discernible flow was stopped.

10. Feb 1969 - Bureau of Reclamation confirmed that the Kritsas wells, located on the north side of the Meeker Dome, were flowing. There was no flow from these wells in August 1968.

11. Fall, 1969 - Kritsas wells plugged.

12. Mar 1970 - Saline seepage from south side of Meeker Dome reported. Inspected by Bureau of Reclamation.

13. May 1971 - Increased seepage reported.

14. Sep 1971 - Area reinspected by Bureau of Reclamation and EPA.

15. 1972 - Problem the subject of numerous meetings and discussions. Head in unplugged Marland Well found to be increasing.

16. 1972 - Dyco Petroleum drilled wildcat well on north side of Meeker Dome. T.D. about 1650 meters.

67, 73, 20, and 11 percent reductions (respectively) in the loads as measured at the downstream sampling location. The reductions in sodium and chloride corresponded very well with the before-plugging loads added by the discharge from the well.

The plan to plug the Meeker Well was initiated with the full, written, concurrence of the Federal Water Pollution Control Agency, the Bureau of Reclamation, and the Colorado Division of Water Resources.

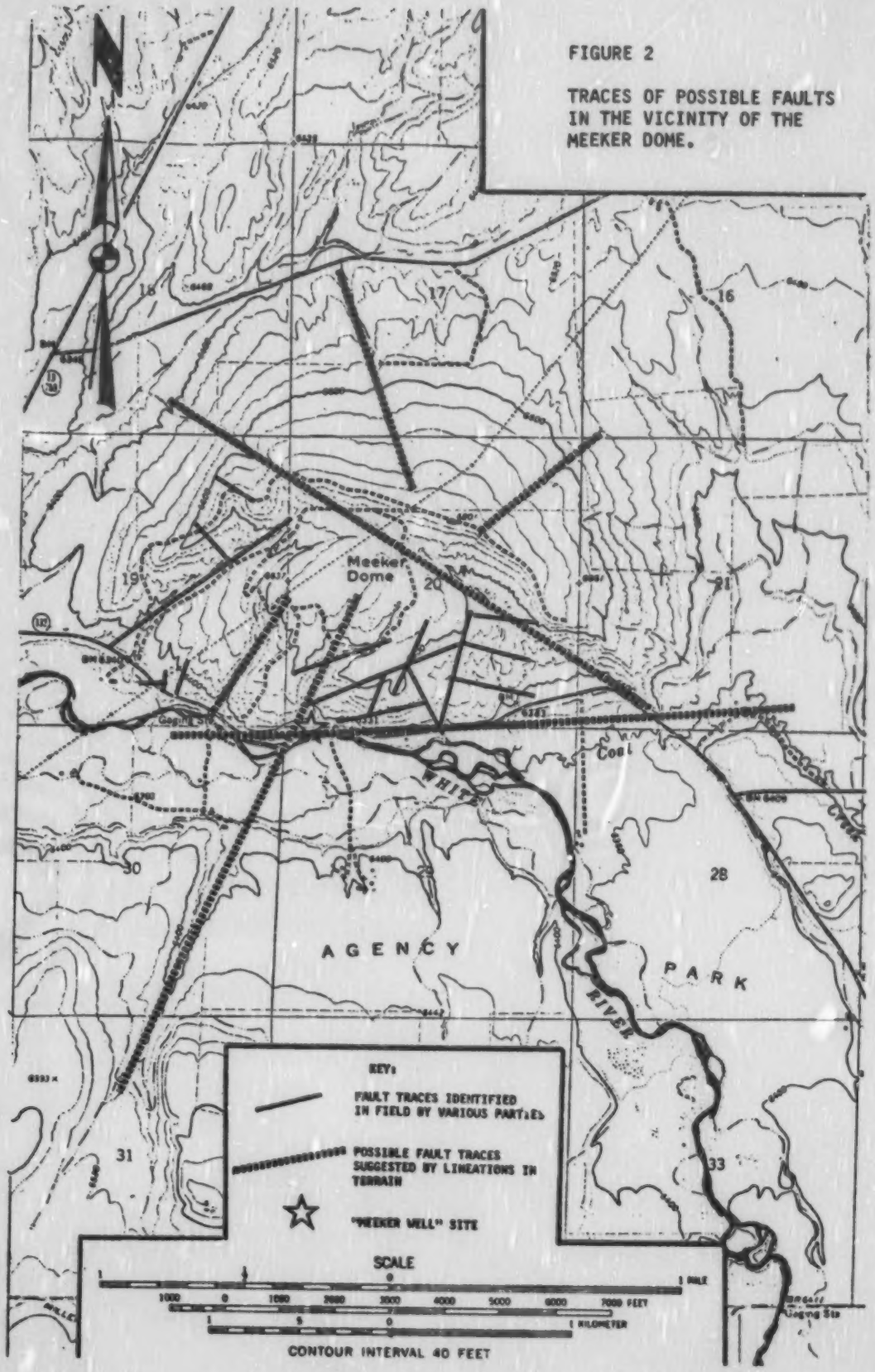
The Meeker Dome is the topographic expression of a local anticlinal uplift which appears to involve all of the sedimentary strata reportedly encountered at depth to about 700 meters. The Meeker Well and at least the Kritsas #1 well are believed to encounter the following formations in order of increasing depth: Dakota (sandstone and shale); Morrison (shale and sandstone); Curtis-Entrada (sandstone); Chinle (shale); Shinarump (conglomerate); Moenkopi (sandstone and shale); Weber (sandstone), and Maroon (sandstone and siltstone). The Entrada and Weber Formations are considered aquifers in the area. Most of the "deep" wells drilled on the Dome have been reported as encountering saline water under pressure at depths corresponding with these aquifers. A more recent dry hole, drilled to a total depth of about 1800 meters, confirmed this sequence.

Most such geologic domes are usually fractured as a result of the intense and localized deformation occurring during uplift. At times these fractures are radial in location, on other occasions they trend in a transverse direction across the topographic high. The Meeker Dome has undergone insufficient exploration to allow identification of any large fractures or faults. An unverified alignment of large-scale topographic lineations in the vicinity of the Dome suggests at least three major lineaments across the Dome, one along the White River which coincides with the probable formation contact (east-west trend), one N50°W through the Dome (Sections 20) and one N20°E across the White River and into the Dome. Smaller normal faults have been identified along the south flank of the Meeker Dome and are shown as solid lines on Figure 2. The occurrance of Mancos Shale on the Dome makes it difficult to identify any displacements on top of the Dome. While recognizing that these lineaments have not been identified in the field, their locations as sketched (Figure 2) may bear some close relationship to certain of the areas of seepage, especially if the fault along the White River does, in fact, exist. An important and as yet unanswered question also exists as to the depth of such faults since if they are deep, they may serve as the primary paths for water to reach the surface.

Subsequent to the plugging of both "Meeker" and Kritsas wells, specific areas of saline ground water seepage were reported to the

FIGURE 2

TRACES OF POSSIBLE FAULTS IN THE VICINITY OF THE MEEKER DOME.



Bureau of Reclamation (Table 1). Field investigations conducted in 1971 further confirmed the existence of four areas of saline ground water seepage along or near the north (or east) bank of the White River, and adjacent to the Meeker Dome. Those areas are shown in Figure 1 and may be described as follows:

1) Anderson #1 drilled by Willard Rease for Dyco Petroleum Company, in September and October, 1972, Section 17, T1N, R93W.

Seepage Area 1: SE1/4, SW1/4, SE1/4, Section 19, T1N, R93W, 0.7 km west of "Meeker Well," south of Colorado Highway 132. Seepage of saline water is occurring along the toe of the bluff (and the highway fill) for a horizontal distance of about 60 meters. This seepage appears to reach an irrigation ditch ("Sheridan-Morton") which parallels the River at this point. The ditch access road appears to have been detrimentally affected by this seepage such that access by vehicle is not possible.

Seepage Area 2: "Meeker Well" Site; SW1/4, Section 20 and NW1/4, Section 29, T1N, R93W, north of Colorado Highway 132, 4.7 km east of Meeker, Colorado. A swampy area exists to the west of the plugged well and saline runoff is directed under the Highway at the west end of the open area, 150 meters west of the marker pipe for the well. Seepage has been noted along the north bank of the White River opposite (south) the plugged well.

Seepage Area 3: "F. Nelson, Lower Prather Property;" NW1/4, NE1/4, Section 29, SW1/4, Section 20, T1N, R93W, south Colorado Highway 132, 0.8 Kilometers east of "Meeker Well." A low pasture area which reportedly received seepage. A drainage ditch leading west from the area contains saline water, much of the lower field appears saturated. Actual seepage into the area was not noted during field investigations though the swampy portions of the field contain saline water.

Seepage Area 4: "Upper Prather Property;" SE Section 20 and NE Section 29, T1N, R93W, south of Colorado Highway 132, 1.3 kilometers east of "Meeker Well." A previously-irrigated and farmed field receives saline seepage from the area bordering Colorado Highway 132 on the south. The head irrigation ditch contains saline water. Newer areas of seepage have occurred near, but upslope from Coal Creek.

Seepage Area 5: "Curtis Creek-Kritsas Wells;" Sections 17 and 8 T1N, R93W, north of local road, about 2.2 kilometers east of Colorado Highway 13-789 and 2.5 kilometers north-northeast of "Meeker Well." In September of 1971, the gully to the north of the well site of Kritsas #2 was wet near and downstream of the well though no seepage specifically from the well could be found.

Chemical analyses have been performed on water samples collected from these areas of seepage and from other locations. The majority of these data are reported here in Table 2. Some variations in the data may have been caused by the method of analysis (field vs. laboratory)

TABLE 2

CHEMICAL QUALITY OF SALINE SEEPAGE IN VICINITY OF MEEKER DOME
(See Text for Location of "Areas")

SEEPAGE AREAS:	AREA 1 "Irrigation Ditch"		AREA 2 "Meeker Well" Area					AREA 3 "Nelson Ranch"				
Parameter (mg/l)	3-17-70[1]	5-4-72[2] (field analysis)	3-17-70[1]	10-11-71[2]	11-20-71[2]	5-3-72[2] (field analysis)	7-11-72[3]	3-17-70[1]	10-11-71[2]	11-20-71[2]	5-3-72[2] (field analysis)	7-11-72[3]
Ca	1,128	2,739	864	2,140	2,700	2,397	870	464	6,440	7,600	6,848	2,500
Mg	388	--	215	--	--	--	200	320	--	--	--	790
Na	5,520	6,200	5,520	2,880	5,000	2,397	5,100	794	3,700	3,400	2,600	4,200
K	63	--	71	--	--	--	60	39	--	--	--	46
HCO_3	112	--	214	--	--	--	209	583	--	--	--	331
Cl	8,910	10,000	7,469	8,800	8,760	8,180	7,900	717	9,500	10,650	6,818	12,000
SO_4	3,694	2,724	4,258	3,000	3,050	3,220	3,100	2,647	2,450	2,350	2,300	2,100
TDS	18,780	29,160	16,990	19,350	19,100	23,088	--	5,030	19,280	22,400	25,110	--
F	0.6	--	1.6	1.4	1.6	--	2.0	--	0.2	0.8	--	1.1
Fe	--	1.3	--	.03	ND	--	--	--	0.15	0.40	1.2	0.11
$MgCO_3$	--	2,397	--	199	219	685	--	--	640	1,190	3,082	--
B	--	--	--	--	0.88	--	--	--	--	0.24	--	--
Br	--	--	--	--	--	--	9.6	--	--	--	--	12
Conductance (µmhos/cm)	--	36,000	--	23,800	25,730	31,200	26,100	--	23,800	27,560	31,000	32,200

ND: Not Detected [1]Bureau of Reclamation [2]Colorado Water Conservation Board [3]USGS

TABLE 2 (continued)

SEEPAGE AREAS:	AREA 4 "Prather Property"	AREA 5 "Kritsas Wells" (Spring nr #2)		KARLAND WELL NE-NE-SW T1N R93W	
Parameter (mg/l)	3-17-70[1]	5-4-72[2] (field analysis)	7-11-72[3]	5-4-72[2] (field analysis)	7-11-72[3]
Ca	1,136	1,370	480	1,370	490
Mg	364	---	660	--	130
Na	1,656	16	2,600	5,900	6,100
K	39	---	12	--	52
HCO_3	445	---	404	--	36
Cl	4,260	3,636	2,800	7,878	7,900
SO_4	1,551	4,800	5,400	3,084	3,000
TDS	9,890	---	--	23,650	--
F	--	---	0.7	--	3.3
Fe	--	1.2	15.3	2.2	.06
$MgCO_3$	--	3,766	--	685	--
B	--	---	--	--	--
Br	--	---	4.8	--	9.2
Conductance (mhos/cm)		18,000	15,300	29,200	26,500

ND: Not Detected [1]Bureau of Reclamation [2]Colorado Water Conservation Board [3]USGS

and by small changes in the sampling locations. The apparent time-dependent variation in calcium and sodium concentrations at the same locations is of interest. Other measurements seem to be in fair agreement with the possible exception of the 3-17-70 measurements of TDS and chlorides at Area 3 (5030 and 717 mg/l) which are quite low compared to the later measurements. However, this again may be a function of sampling location. No consistent set of chemical relationships have been derived for the seepage areas sampled. Suffice to say that the quality of the seepage water is not good.

The Dyco hole, Anderson #1, encountered water in the Morrison, the Entrada, and in the Weber Formations. No water quality samples were obtained to our knowledge.

No data were collected prior to the plugging of the "Meeker Well" that could serve to verify a relationship in time between the seepage and the plugging of wells drilled near the Meeker Dome. More importantly, no official report describing the hydrologic condition of the Dome before drilling commenced has been found. A Mr. Arthur Wilbur of Meeker has reported to Gene Hampton of the U.S.G.S. that warm salt springs along the White River between Sections 20 and 29 (T1N, R93W) were used for bathing by Indians around 1881.

The remainder of this report presents the results of more current efforts to both evaluate the hydrologic system around the Meeker Dome and to explore methods of controlling problematical seepage.

RESULTS OF RECENT INVESTIGATIONS

Results of Infra-red Imagery Aquisition in the Vicinity of the Meeker Dome

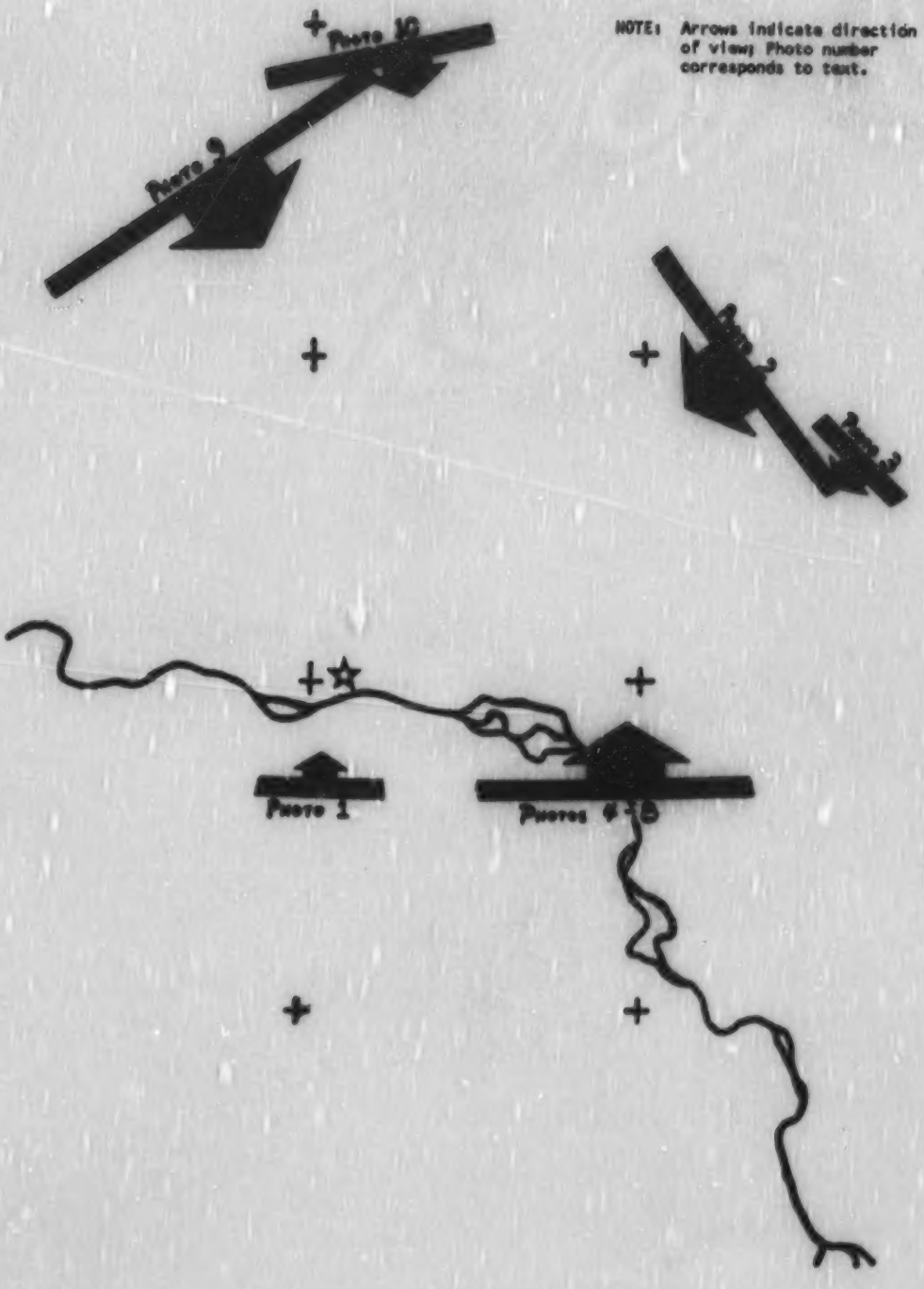
In order to better assess the geohydrologic situation extant around the Meeker Dome, EPA requested that its Field Investigations Center at Denver acquire and interpret low altitude infra-red imagery of the Dome area including the areas of seepage and the White River. The area was flown on August 7, 1972. Selected photographs from this mission are presented here (photographs are contained in our copies of the report). The general views of the photographs are positioned on Figure 3 and its overlay.

Noteworthy features of these photographs are the areas of seepage and "distressed" vegetation. The infra-red film was used to assist with the identification of areas of seepage to the surface (presence of water at the ground surface and the presence of chlorophyl) and degradation of foliage (lack of chlorophyl). Surface accumulations of salts were also noted.

FIGURE 3--OVERLAY

LOCATION OF PHOTOGRAPHS

NOTE: Arrows indicate direction of view; Photo number corresponds to text.



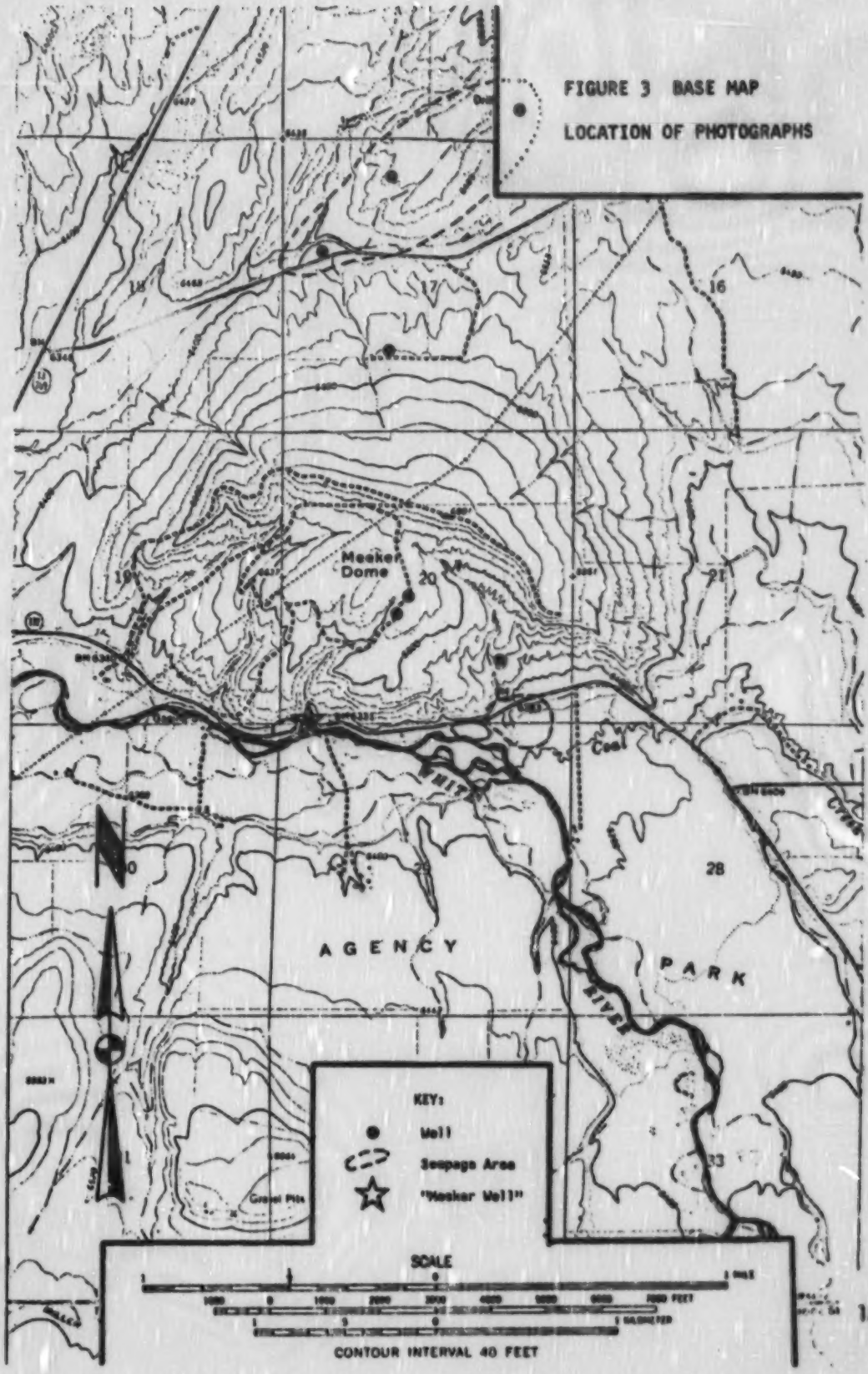


FIGURE 3 BASE MAP

LOCATION OF PHOTOGRAPHS

The "Meeker Well" site is shown in Photograph 1 (print numbers 185-7 and 185-8). The well is located in the turnout near the dark, straight material (timber or pipe?) stored on the ground (arrow on right). Seepage appears to occur into the swampy area to the left (west) of the well and saline water drains to the White River through the ditch leading from under the highway opposite the left end of the "swamp" (arrow on left). The fact that seepage has previously been noted along the north bank of the White River, near the well, suggests further that the relatively vigorous vegetative growth near the well and leading toward the River is related to seepage. Note that some of this more vigorous vegetative growth correlates with a lineation across the highway. This may be the location of the old culvert which carried the discharge from the well into the White River.

Photograph 2 consists of two prints (185-25 and 185-26) which give a perspective of the Meeker Dome from the northeast flank looking southwest.[1]) The White River (flowing to the right) may be seen at its intersection with the power transmission lines along the rear side of the terraced channel. This White River terrace in "Agency Park" is notable. The spots in the light-colored fields are generally considered to be "wet spots," possibly related to ground water seepage. The fields on the top of the Dome were not irrigated at the time of the inspection.

Photograph 3 consists again of two prints (185-29 and 185-30) which provide a view of the Meeker Dome from the east and show some apparent deficiencies in an irrigation ditch. Photograph 3a shows one of the fields previously viewed in Photograph 2 and also shows an irrigation ditch which runs along the east side of the Meeker Dome. The change in color downhill from the non-irrigated land to the irrigated land is notable. Photograph 3b is used to point-out two locations where significant quantities of water appear to be leaking from the ditch (the middle arrows) and other areas of possible seepage (outside arrows) both from the ditch and from the Dome. Note also that the upper left corner of Photograph 3b shows a portion of the upper Prather property and a similar change in color between the areas above and below the irrigation ditch.

Photographs 4 through 8 portray the upper Prather property, or Seepage Area 4, in more detail. This area is located along the southeast flank of the Meeker Dome and is drained by Coal Creek as shown

1) Note the plume from the asphalt batch plant in the upper left of the photographs. Temperature inversions cause significant concentrations of the particulate material discharged.

Photo 1 (185-7 and 185-8)

"Meeker Well" Site - August, 1972
White River in foreground, looking North. Well site & surface drain indicated by right & left arrows

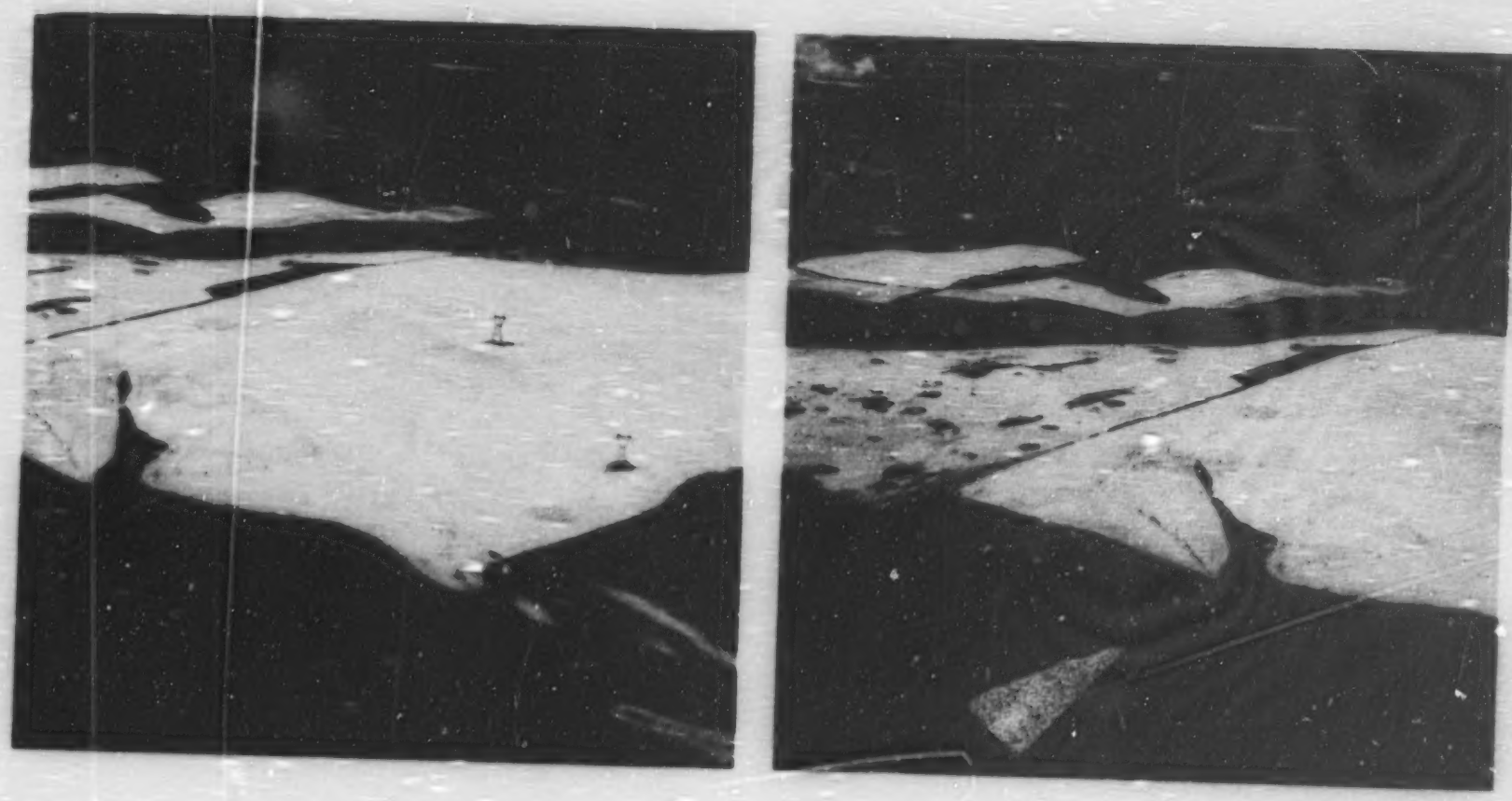


Photo 2 (185-25 and 185-26)

Two views of Meeker Dome from the northeast showing cultivated areas - August, 1972.

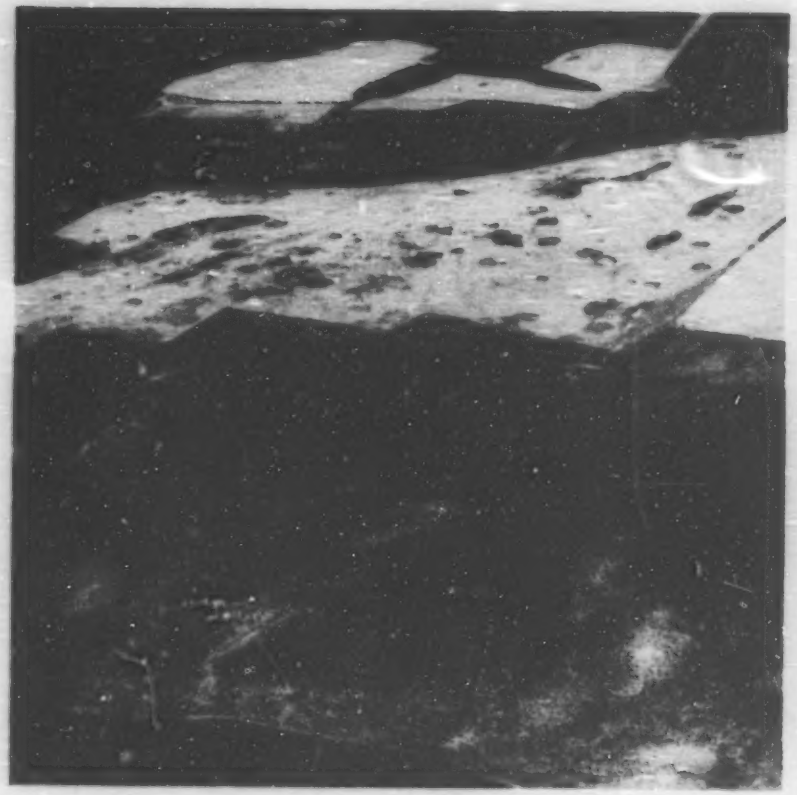


Photo 3a (185-29)

"Spotted" Field on Meeker Dome showing "wet" areas.

Photo 3b (185-30

Seepage Areas near Irrigation Ditch, east side of Meeker Dome.

Photo 4 (185-1)

East end of Upper Prather Property.
Seepage Area #4 - August, 1972.

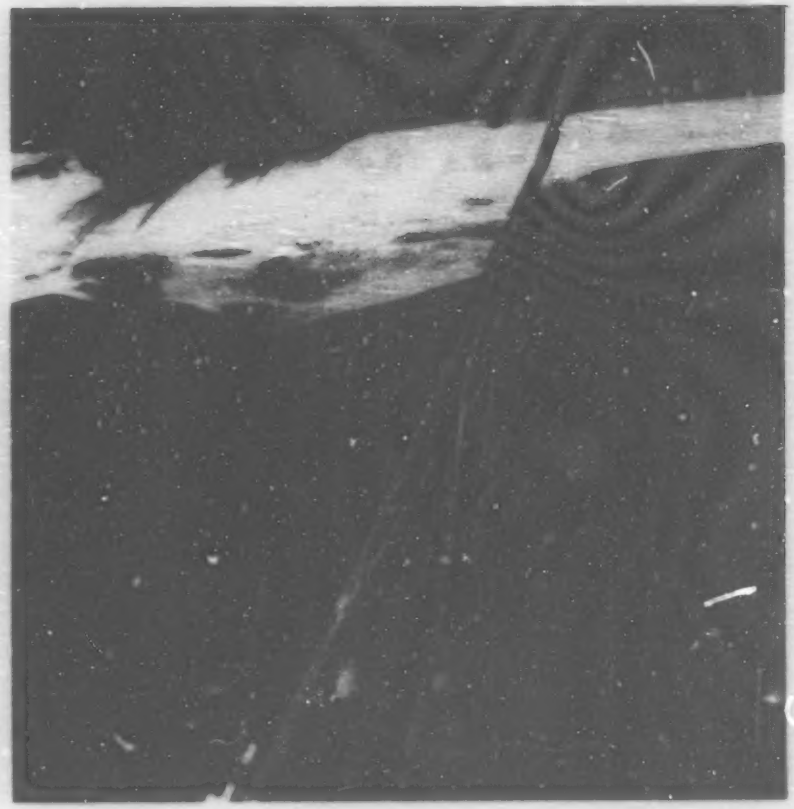


Photo 5 (185-2)

Upper Prather Property - Seepage Area #4.
Coal Creek below white area - August 1972.

Photo 6a (185-3)

Upper Prather Property - west end. Seepage Area #4. Confluence of Coal Creek & White River - August, 1972

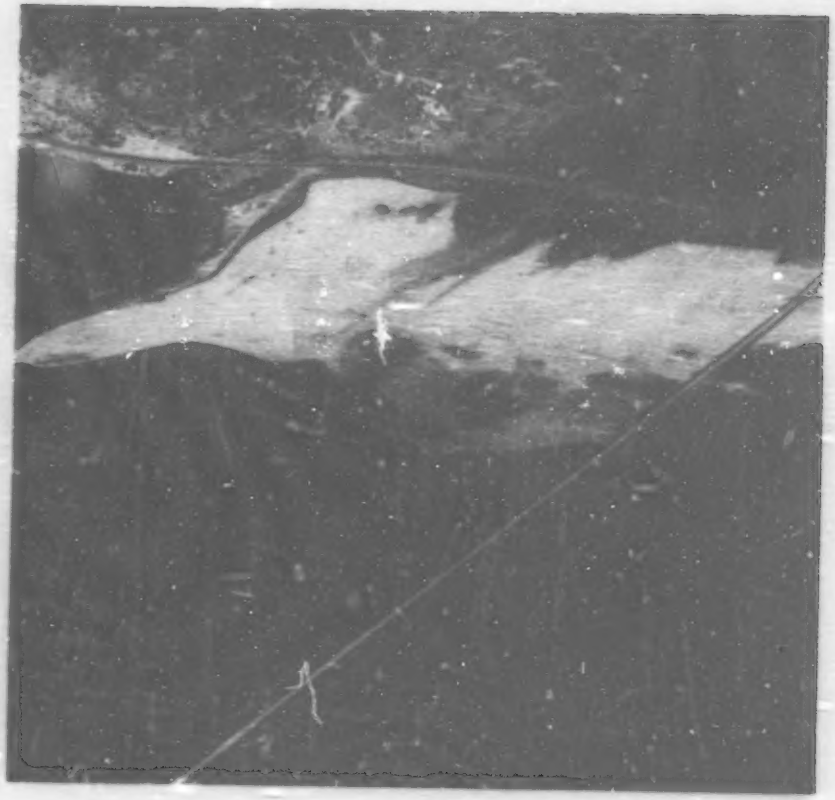


Photo 6b (185-6)

Upper Prather Property - Seepage Area #4. True color - August 1972

Photo 7 (185-4)

Nelson Property - Seepage Area #3 east end. Vehicles at campground area - August, 1972

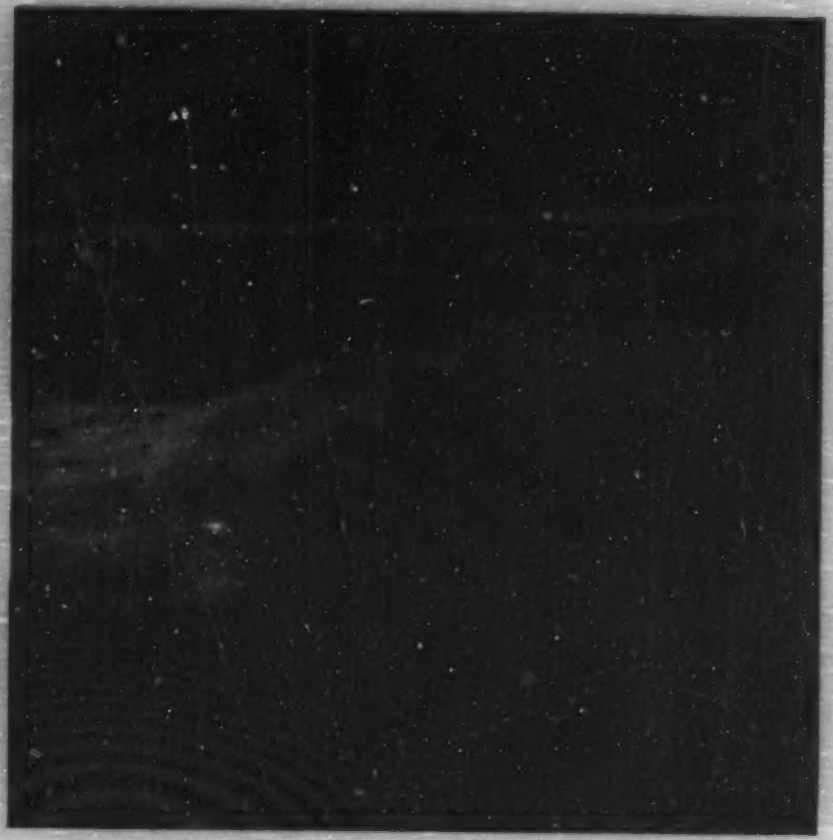


Photo 8 (185-5)

Nelson Property - Seepage Area #3. Area bounded by roads and northern (upper) meander of White River - August, 1972.

Photo 10 (185-22 thru 24)

Kritsas #2 Well - north side Meeker Dome
August, 1972

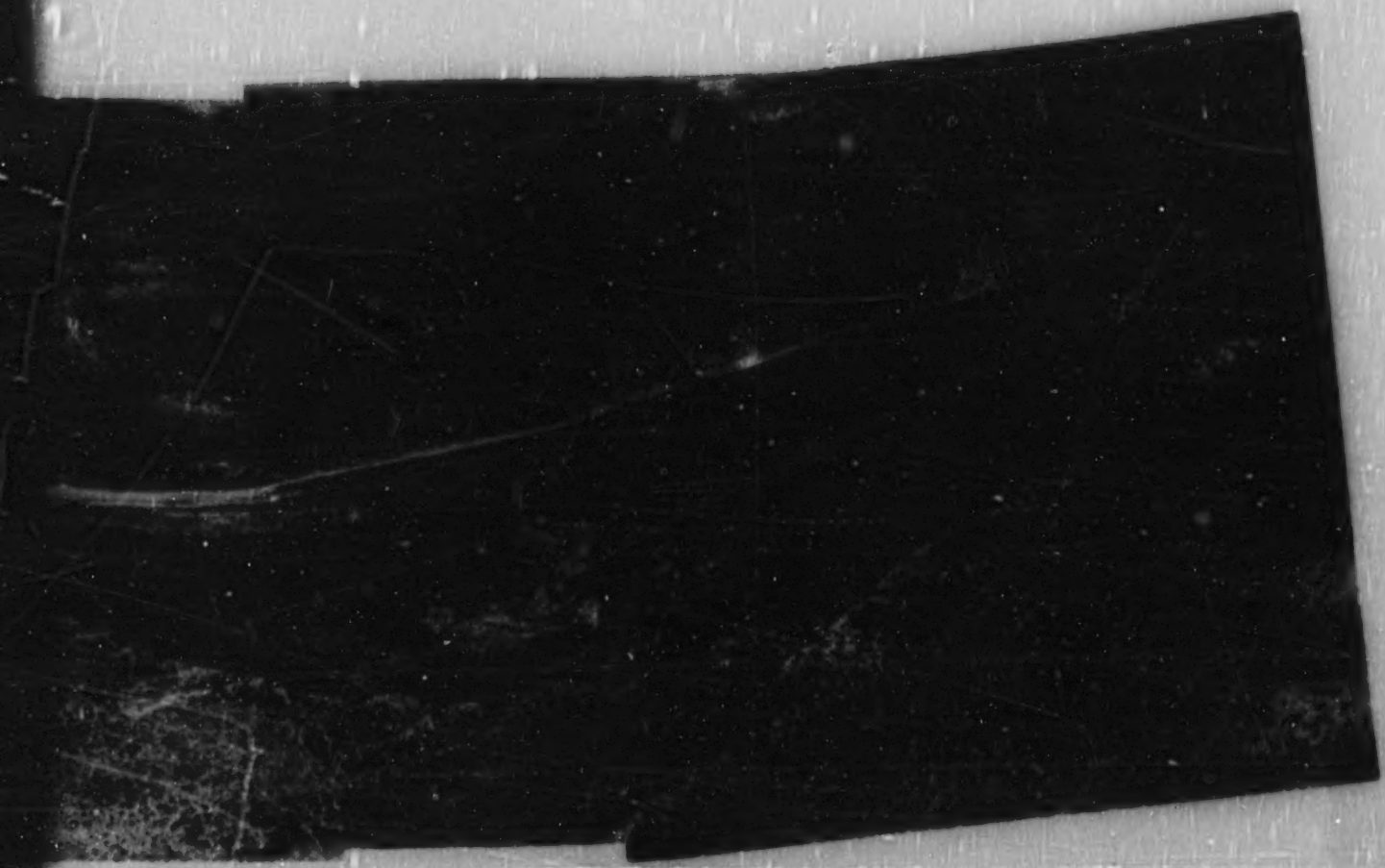
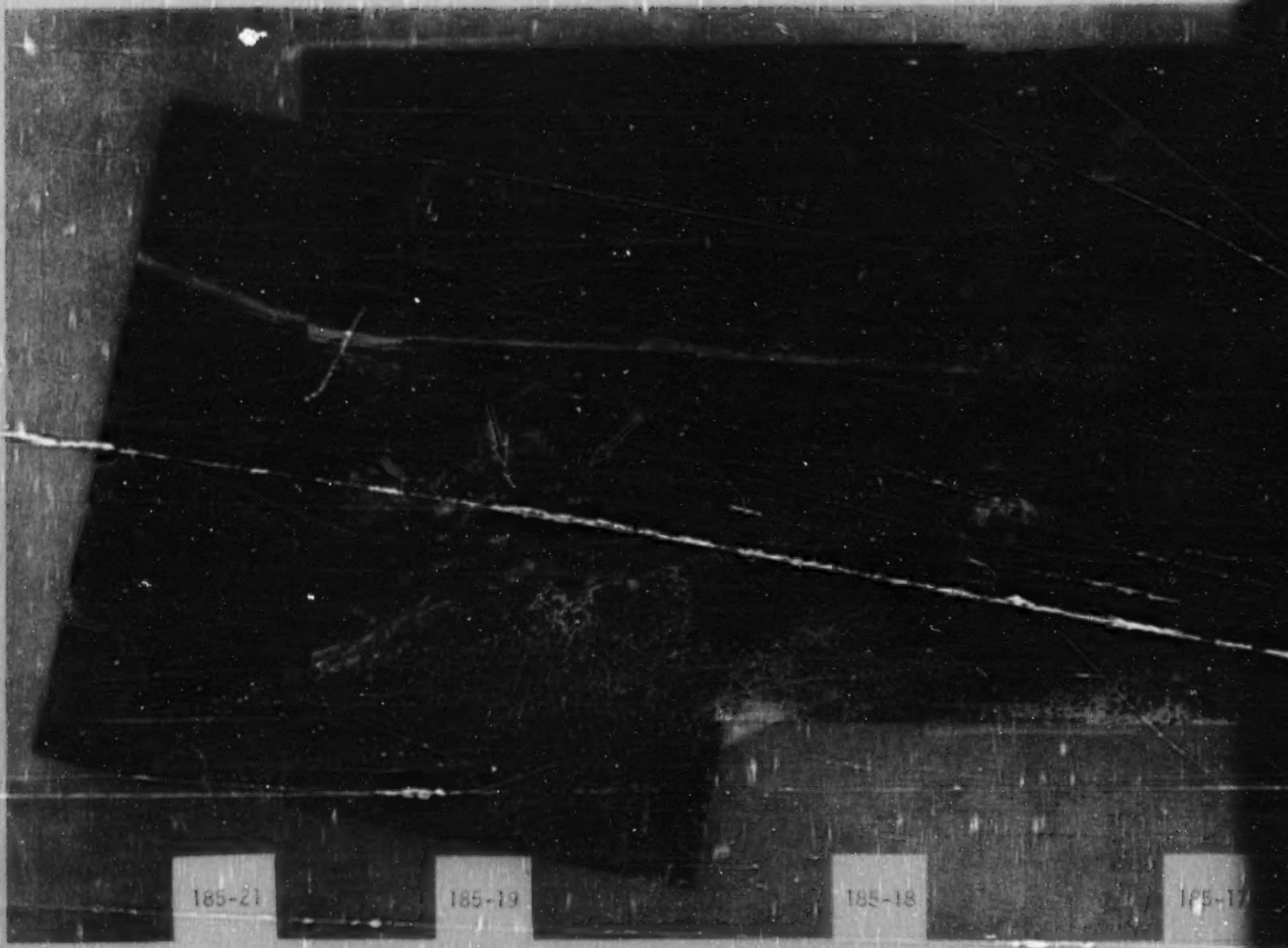
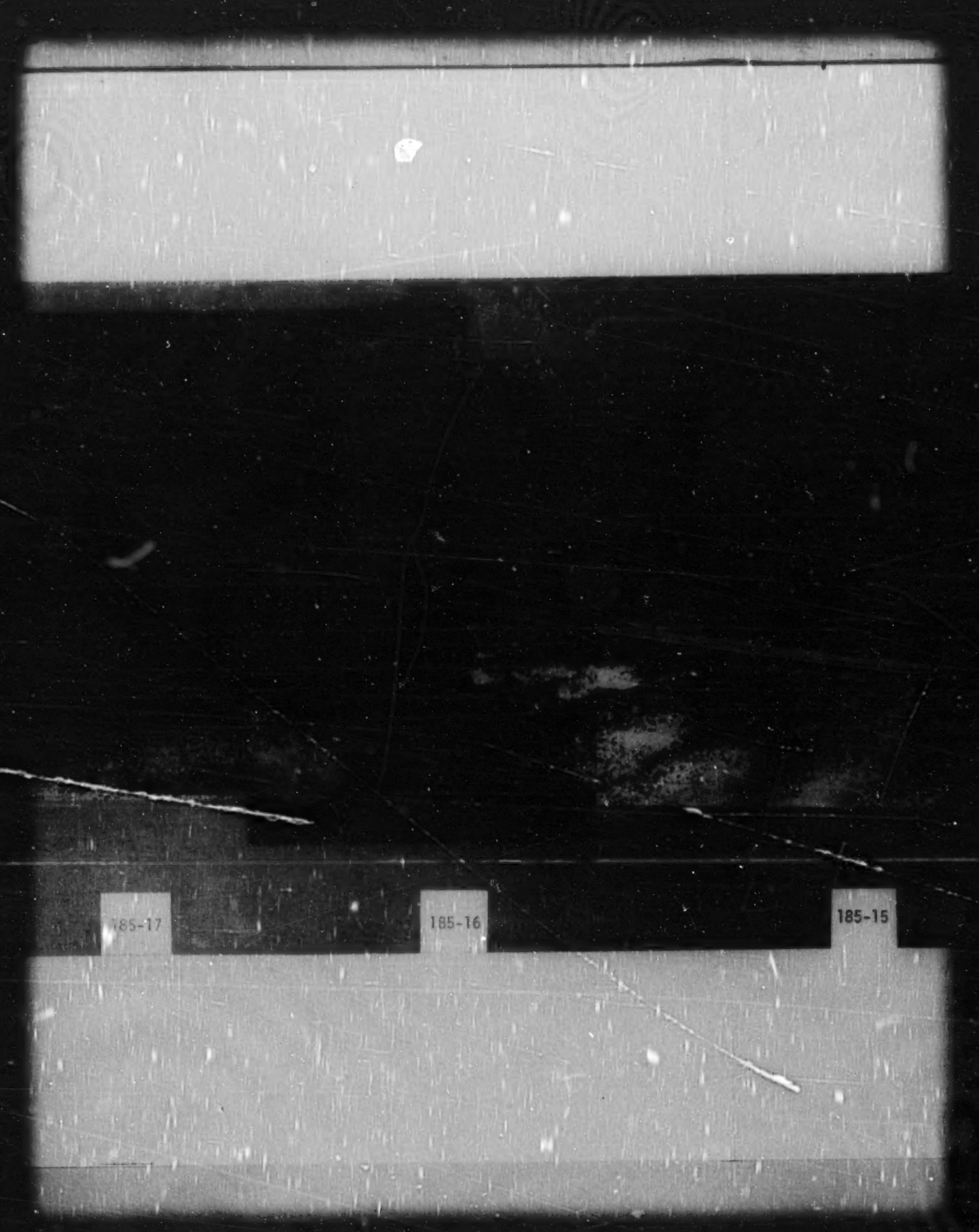


Photo 10 (185-22 thru 24)

Kritsas #2 Well - north side Meeker Dome
August, 1972


185-21
185-19
185-18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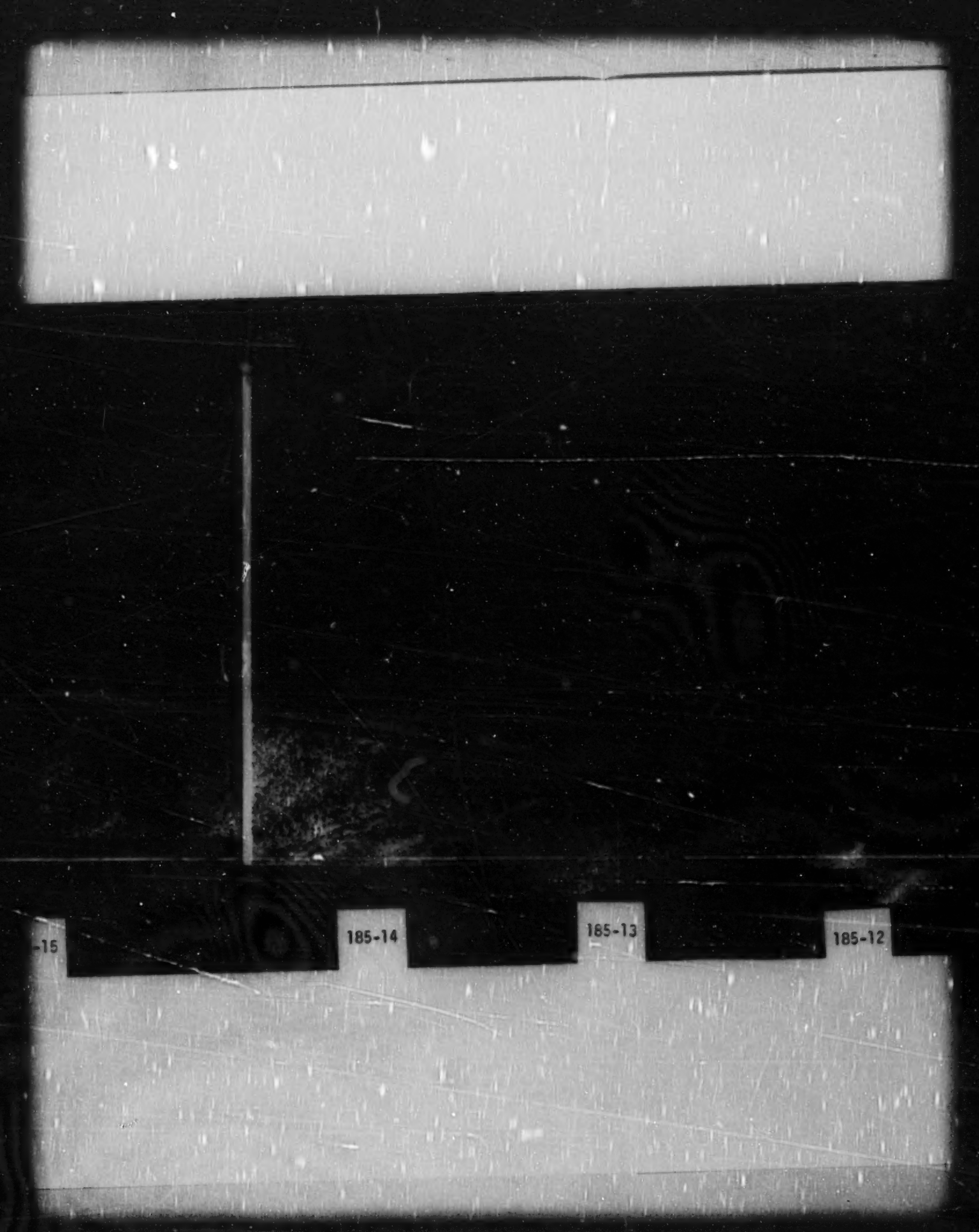
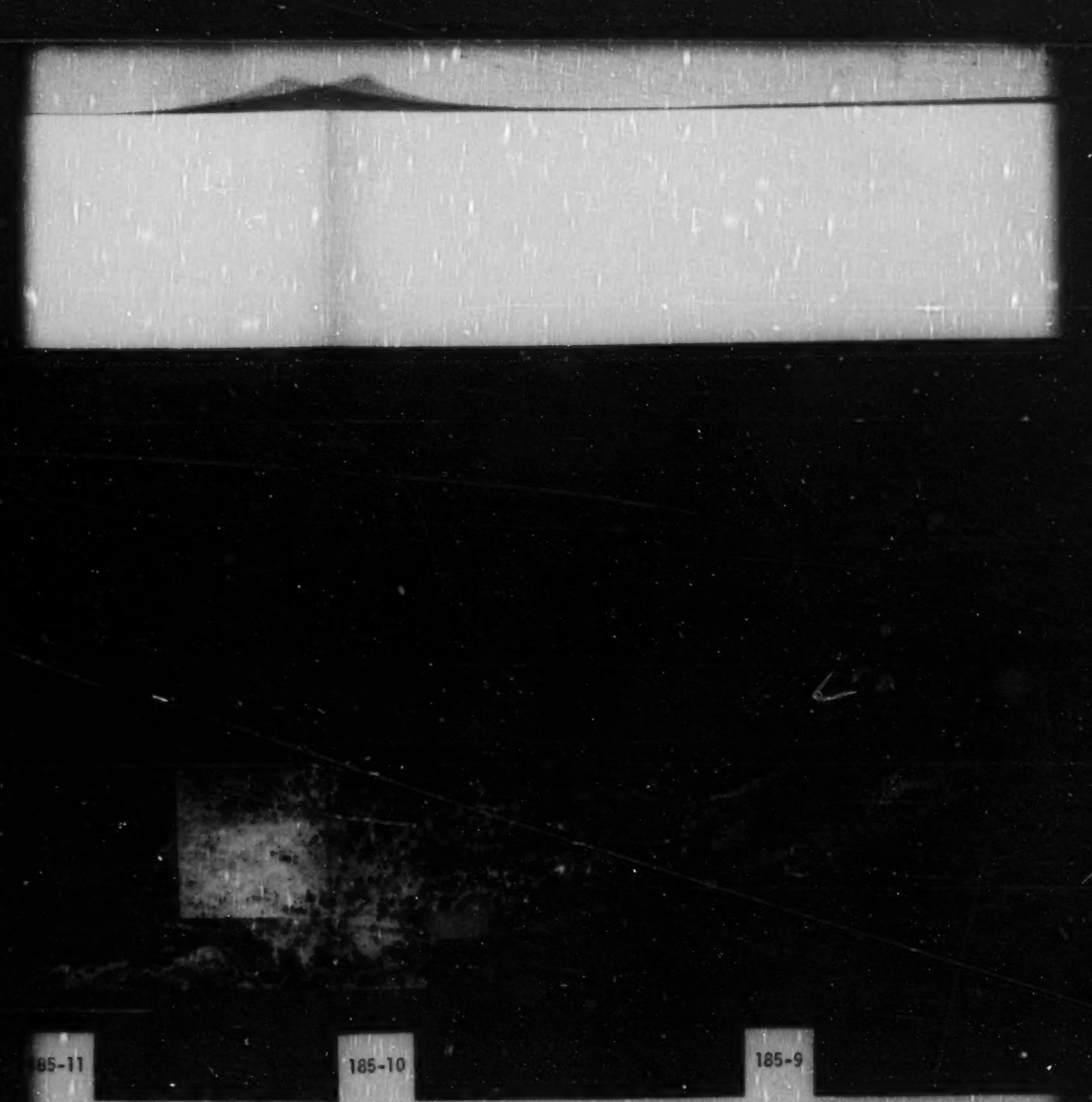
185-16
185-15


-15
185-14
185-13
185-12

Mosaic View of Drainage from n
of Hooker Dome near and downst
Kritsas #1 Well - August, 1972



Mosaic View of Drainage from north side of Meeker Dome near and downstream of Kritsas #1 Well - August, 1972.

in Photos 4 through 6. Photographs 7 and 8 also show the Nelson property which has been referred to previously as Seepage Area 3. As noted, the color distinction between irrigated and non-irrigated land is great (Photograph 4; 185-1) though a true color photograph (Photograph 6b, 185-6) shows a somewhat similar distinction. Photos 5 and 6a (185-2 and 185-3) give the best portrayal of the impact of saline seepage on the tract of land between Colorado Highway 132 and Coal Creek. This dark area shows a definite downhill trend with a minor seep indicated to the east of the ranch road near its junction with the irrigation ditch. No indication of equally-stressed areas was found to the south of Coal Creek.

Photographs 7 and 8 (185-4 and 185-5) progress downstream from the previously described views to include the Nelson property or Seepage Area 3. This area is low-lying land bordered by the highway embankment and shale in the background and the White River in the foreground. Seepage may occur along the embankments in the background but much of the discoloration below and to the west of the vehicles is caused by deposition of weathered shale derived from the embankment. Some textural variations in the color of the vegetation on the property is discernable, but no indication of impacts similar to that shown to the east (on the upper Prather Property) is evident.

Photograph 9 is comprised of 12 prints (185-9 through 185-19 and 185-21) which can be pieced together in a rough mosaic. The resulting photograph provides a view of the north side of Meeker Dome extending approximately from Colorado Highway 13-789 on the right (west) to the Kritsas #2 well on the left (east). The mosaic then covers the majority of the drainage path from the north flank of the Meeker Dome to Curtis Creek with the "upstream" direction to the left. We believe that the most important features shown in this view are the two degraded stream-reaches which appear as yellowish-green and brownish areas near the Kritsas #2 well (two arrows on left) and in the area where the stream intersects the road. The "distressed" area in the foreground originates from the vicinity of the Kritsas #1 well. The red-orange colors that denote the stream elsewhere suggest more vigorous vegetation. The distressed vegetation appears to be the result of the intrusion and evaporation of saline water since the surface soil is encrusted with salt. The relatively vigorous vegetative growth appears to be related both to an interception of shallow ground water by certain stream channels and by recent rains. More localized areas of ground water seepage are evident along the right (east) side of the mosaic while the red-orange color reappears in the gulleys at the extreme right of the photograph. This color-response also appears related to recent precipitation (note that a similar color response is shown along the edges of the highway near the Kritsas Well). The ponded area is located at the toe of one of the lineations referred to in the earlier section on "Background."

Photograph 10 is another composite (prints 185-22 through 185-24) which present another view of the Kritsas #2 well as identified previously on Photograph 9. Notable is the apparent inflow of saline water on the right (east) side of the mosaic (see arrow). The change in color along the drainage near the Kritsas #2 clearing is quite evident.

In summary, the infra-red imagery indicates that the ground surface of the Meeker Dome intersects the local water table in locations both along the south and north flanks of the Dome and that some of the seepage has caused varying degrees of distress for native and introduced vegetation. The areas of seepage as shown by the photographs correlate with the findings of on-site inspections though the seepage seems greater on the top and north side of the Dome than was suspected. Limited review of the imagery has not revealed any new information regarding the structural fracture system of the Meeker Dome.

Specific Conductance and "Salinity" Measurements in the Vicinity of the Meeker Dome.

During the period 18-20 October 1972, Mr. Robert Fox of EPA measured the specific conductance at numerous points along the White River to determine the impact on water quality of saline discharges on that reach of the River (Figure 4). These data are presented in Table 3 and are graphically summarized in Figure 5. The data reflect an increase in salinity which is further quantified in Table 4. This Table presents sodium, chloride, and total dissolved solids data for samples collected from the White River on October 18 and 19 upstream and downstream of the areas of active seepage.

The specific conductance data in Figure 5 are presented in terms of either average conductance across the channel or as a single measurement, usually made near the north or east bank of the White River, the bank closest to the areas of seepage identified to date. The average flow in the White River was 520 cfs during the period of measurements (18-20 October 1972) Figure 5 also contains selected measurements of specific conductance made by the Colorado Water Conservation Board (Mr. Carter Hutchinson) in May of 1972 (3-5 May) and October, 1971. The May measurements showed appreciably lower (25 percent) conductance than was measured in October of 1972. But the River flow in May was on the order of 710 cfs or 27 percent higher than in October. Since salinity concentrations in the White River are known to vary inversely with flow, the difference in conductance between May and October may be expected as the result of higher flows in May.

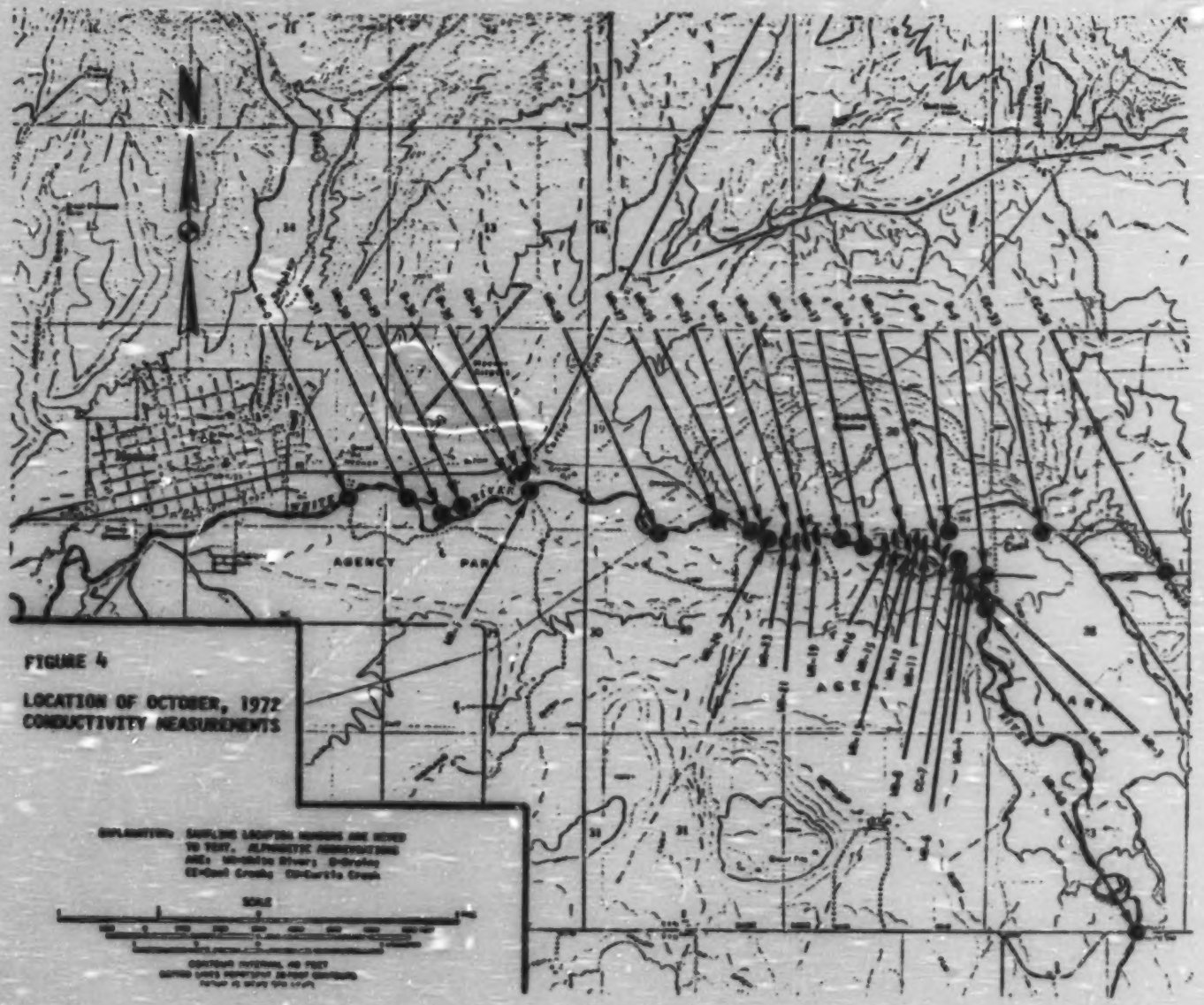


FIGURE 4

LOCATION OF OCTOBER, 1972
CONDUCTIVITY MEASUREMENTS

TABLE 3

CONDUCTIVITY RECONNAISSANCE OF

"MEEKER WELL" AREA

Meeker, Colorado
October 1972

Station	Date	Time	°C Temp.	µmhos/cm Conduc.	Location
	-Progressive Downstream Order-				
WR-40	10-18	1415	10.5	350	East bank - Upstream USGS stream gaging station.
"	"	1820	--	370	East bank
"	10-19	0733	--	380	East bank
"	"	0733	--	380	West bank
"	"	1145	--	370	East bank
"	"	1832	--	380	East bank
"	10-20	0815	--	380	East bank
"	"	1210	--	370	East bank
WR-2	10-18	1746	11.0	360	Midpoint of bridge at farm 400 meters upstream of Coal Creek confluence with White River.
"	10-19	1126	9.5	370	" " "
WR-3	10-19	0906	8.5	380	East bank - 30 meters downstream of WR-2.
WR-4	10-19	0918	8.5	380	East bank - 120 meters downstream of WR-3.
D-5	10-18	1802	10.5	930	Irrigation ditch - 20 meters upstream of confluence. Ditch is
"	10-19	0922	9.0	800	located just south of Coal Creek.
WR-6	10-19	0925	8.5	385	20 meters downstream of D-5; 2 meters from east bank.
CC-7	10-18	1758	11.5	2750	Coal Creek - 30 meters upstream of confluence with White River.
"	10-19	0848	9.5	2790	" " "

Station	Date	Time	°C Temp.	µmhos/cm Conduc.	Location
	-Progressive Downstream Order-				
WR-8	10-19	1000	9.0	*1165	East bank - 45 meters downstream from Coal Creek.
"	"	0940	9.0	* 740	5 meters from east bank.
"	"	1000	9.0	* 595	1/4-pt. of stream (from east).
"	"	1000	9.0	* 380	1/2-pt.
"	"	1000	9.0	* 380	3/4-pt.
"	"	1000	9.0	* 380	West bank.
D-9	10-19	1017	10.0	2740	Drainage ditch just below WR-8.
WR-10	10-19	1025	9.5	*1010	45 meters downstream from WR-8; 3 meters from bank.
WR-11	10-19	1030	9.0	560	60 meters downstream from WR-10.
WR-12	10-19	1036	9.0	560	45 meters downstream from WR-11.
WR-13	10-19	1045	9.0	500	60 meters downstream from WR-12.
D-14	10-19	1051	9.5	1120	Drainage ditch entering entering White River 15 meters downstream from WR-13.
WR-15	10-19	1057	9.0	485	30 meters downstream from confluence of ditch.
WR-16	10-19	1415	9.5	605	90 meters downstream from WR-15.
WR-17	10-19	1436	9.5	510	Apprx. 200 meters downstream from WR-16.
WR-18	10-19	1444	9.5	530	Apprx. 100 meters downstream from WR-17.
WR-19	10-19	1452	9.5	500	30 meters downstream from bridge on private driveway.
WR-20	10-19	1456	9.5	500	Directly opposite well-marker pipe. 3 meters from north bank.
WR-21	10-19	1500	9.5	500	100 meters downstream from WR-20.
D-22	10-19	1607	11.0	2030	Highway culvert drain at west end of marshy area around well.
WR-23	10-19	1510	9.5	600	75 meters downstream from WR-21 and 12 meters downstream from discharge D-22.
WR-24	10-19	1518	9.5	550	150 meters upstream of USGS gaging station (WR-26).

Station	Date	Time	°C Temp.	µmhos/cm Conduc.	Location
	-Progressive Downstream Order-				
WR-25	10-19	1524	9.5	545	60 meters upstream of WR-26.
WR-26	10-18	1500	11.0	525	North bank at downstream USGS gaging station bridge.
"	"	"	"	500	N-1/4-pt.
"	"	"	"	465	Mid-pt.
"	"	"	"	445	S-1/4-pt.
"	"	"	"	440	South bank.
"	"	1844	--	485	Mid-point of stream.
"	10-19	0712	--	480	" " " "
"	"	1209	--	480	" " " "
"	"	1620	9.0	550	1/4 point from North bank.
"	"	1845	--	525	Mid-point of stream.
"	10-20	0745	7.0	510	" " " "
"	"	1240	--	500	" " " "
WR-27	10-19	1640	9.0	530	300 meters downstream from WR-26.
WR-28	10-19	1650	9.0	505	120 meters downstream from WR-27.
WR-1	10-18	1650	10.5	475	Mid-point of river at bridge on private driveway.
"	10-19	1220	9.5	485	" " " " " " "
CU-34	10-18	1610	--	8000	Curtis Creek upstream of confluence with ditch overflow.
"	10-19	0910	8.0	5280	" " " " "
D-35	10-19	0915	8.0	610	Irrigation ditch at inverted siphon under Curtis Creek.
D-36	10-18	1610	--	**3700	Irrigation ditch overflow into Curtis Creek.
"	10-20	0917	8.0	**3050	" " " "
CU-29	10-19	1716	10.0	4620	Curtis Creek - 15 meters upstream of confluence with White River.
WR-30	10-19	1721	9.0	*** 595	18 meters downstream of Curtis Creek confluence.
WR-31	10-19	1730	9.0	560	Midway between WR-1 and WR-0.

Station	Date	Time	°C Temp.	µmhos/cm Conduc.	Location
	-Progressive Downstream Order-				
WR-0	10-18	1547	11.5	465	North bank of stream at bridge near Veterinary Bldg.
"	"	"	"	475	Mid-pt.
"	"	"	"	500	South bank.
"	10-19	1342	10.0	490	Mid-point of river.
CC-32	10-19	1805	10.5	1590	Coal Creek at County Road #6 bridge.
CC-33	10-19	1815	10.0	1490	Coal Creek at highway #132 bridge.

Flow of Coal Creek — 5.7 cfs measured upstream of confluence with White River

*At these locations the river channel at which the conductivity was measured carried only about 3/4 of the full river flow.

**May include effects of Curtis Creek contamination at measuring point.

***Conductivity measurement made in a secondary river channel containing only about 1/4 of the full river flow.

NOTE: Rain began falling at 1400 hours and continued throughout the afternoon of 10-19-72, causing increased flow at D-22 and, thereby, higher conductivities than normal at downstream stations.

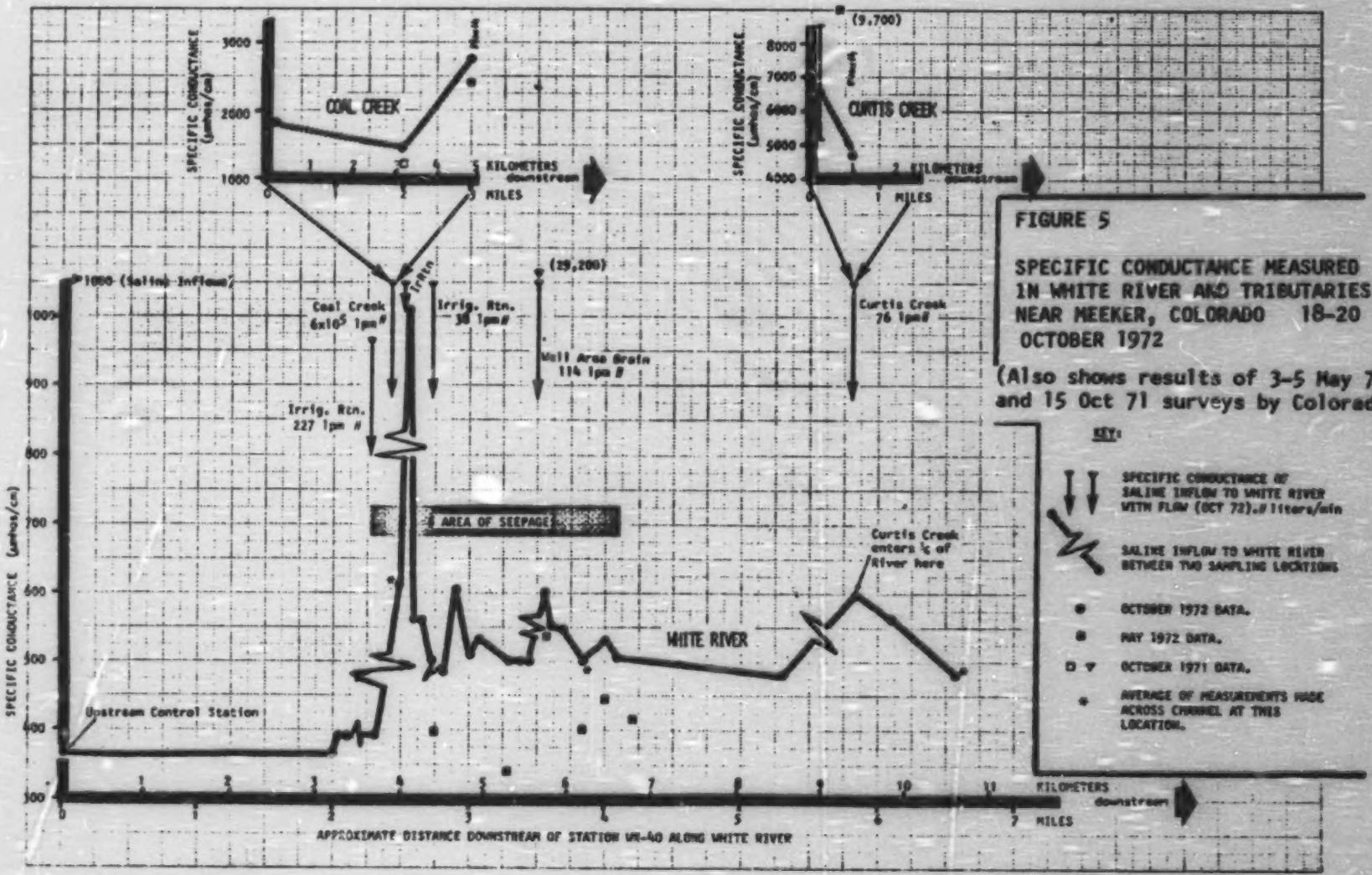

COAL CREEK
SPECIFIC CONDUCTANCE (umhos/cm)
KILOMETERS downstream
MILES
CURTIS CREEK
(9,700)
(29,200)
1000 (Saline) Inflow
Coal Creek 6x10^5 lpm
Irrig. Rtn. 38 lpm
Irrig. Rtn. 227 lpm
Wall Area Drain 114 lpm
Curtis Creek 76 lpm
AREA OF SEEPAGE
Curtis Creek enters ½ of River here
WHITE RIVER
Upstream Control Station
APPROXIMATE DISTANCE DOWNSTREAM OF STATION WR-40 ALONG WHITE RIVER
KEY:
SPECIFIC CONDUCTANCE OF SALINE INFLOW TO WHITE RIVER WITH FLOW (OCT 72). # liters/min
SALINE INFLOW TO WHITE RIVER BETWEEN TWO SAMPLING LOCATIONS
OCTOBER 1972 DATA.
MAY 1972 DATA.
OCTOBER 1971 DATA.
AVERAGE OF MEASUREMENTS MADE ACROSS CHANNEL AT THIS LOCATION.

FIGURE 5

SPECIFIC CONDUCTANCE MEASURED IN WHITE RIVER AND TRIBUTARIES NEAR MEEKER, COLORADO 18-20 OCTOBER 1972

(Also shows results of 3-5 May 72 and 15 Oct 71 surveys by Colorado)

TABLE 4

CHEMICAL DATA FOR WHITE RIVER

Samples	Concentrations and Flow									
	18 Oct 72 (mg/l)				Flow	19 Oct 72 (mg/l)				Flow
Location	Na	Cl	SO_4	TDS	(cfs)	Na	Cl	SO_4	TDS	(cfs)
#2 - White River, 0.4-km upstream of Coal Creek, at farm bridge.	3.7	2.7	61	230	544	3.7	1.7	62	238	512
#1 - White River, 1.9-km upstream of Meeker, due south of Rte. 13-789 and 132 junction, at bridge.	18.0	21.7	77	294	552	18.5	22.7	78	294	514
#0 - White River, 0.5-km upstream of Meeker, 1.4-km downstream of #1 and 0.8-km downstream of Curtis Creek.						19.0	21.2	84	302	508

Figure 6 presents some detailed measurements of specific conductance performed across the channel at location "8," 30 meters downstream of the confluence of the White River and Coal Creek, at location 26, at the downstream gaging station about 450 meters downstream of the culvert drain from the Meeker Well area of seepage, and at location "0," on the White River about 1000 meters downstream of its confluence with Curtis Creek. These data verify the higher concentrations of dissolved solids along the east or north banks, near the areas of seepage. The data also show a minor variation in conductance with time over the three-day period.

With respect to Figures 5 and 6, it is important to note that the position of the conductance measurement relative to the river bank and the amount of the White River in the particular channel receiving the seepage caused some apparent variations in specific conductance at certain locations. In progressive downstream order, station 8 (606 μmhos/cm, ave,) measured the impact of Coal Creek across 75 percent of the channel (also, a cow had stirred the water shortly before some measurements); station 10 (1010 μmhos/cm) also measured only 75 percent of the flow and was a single, "near-bank" measurement. Similarly, station 30 measured the impact of Curtis Creek on only 25 percent (approximately) of the total flow of the White River at that point. These factors may result in deceptively high conductance at these points, but have no bearing on the measurement of the overall trend in salinity throughout the reach since measurements of this trend were made across the entire channel in well-mixed areas of the White River.

A check of the relationship between the specific conductance measurements and laboratory determinations of total dissolved solids (TDS) indicates that the two measurements agree fairly well using a ratio of TDS to conductance equal to 0.625.

The salinity data gathered in October (1972) show that the White River, as it passes along the south flank of the Meeker Dome, experiences an increase in salinity of 27 percent during the conditions obtaining. This increase is comprised of 21 tons per day (tpd) of sodium (5.2. tpd Na at location #2 to 26.0 tpd Na at location #1), 29 tpd of chloride (3.1 tpd to 31.7 tpd) and 24 tpd of sulphate (87.7 tpd to 111.4 tpd); thereby contributing to an increase of 89 tpd of dissolved solids (331 tpd to 420 tpd). As shown in Table 5, this increase along the White River appears significantly less than was measured prior to August, 1968 (the date the Meeker Well was plugged). The comparison of increases should be qualified due to the fact that while the upstream station location remains approximately the same for pre- and post- plugging sampling, our October data for the downstream station were collected upstream of Meeker and of Curtis Creek while the other, long term

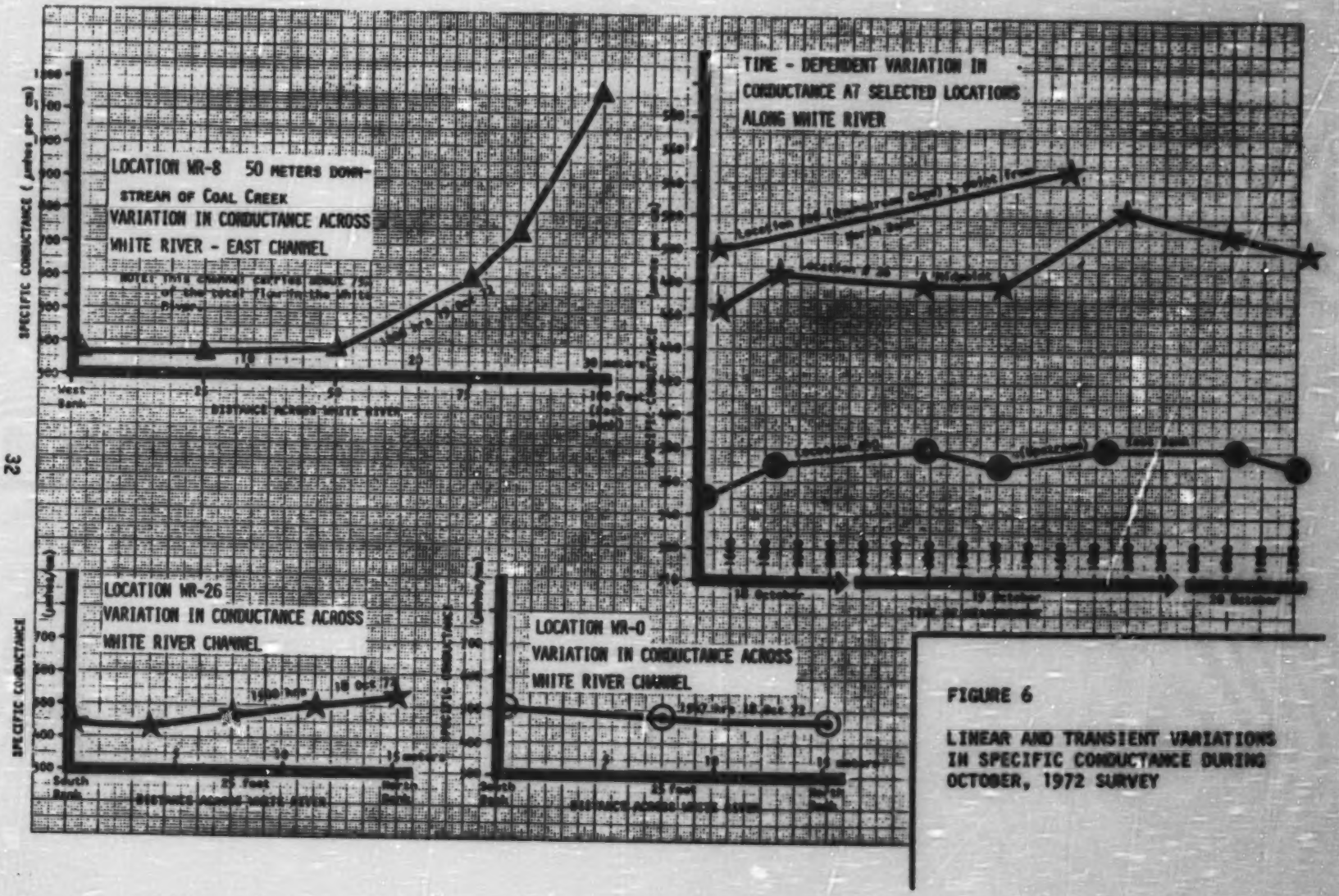


FIGURE 6

LINEAR AND TRANSIENT VARIATIONS IN SPECIFIC CONDUCTANCE DURING OCTOBER, 1972 SURVEY

TABLE 5

COMPARISON OF INCREASE IN SALINITY MEASURED IN OCTOBER 1972 WITH THAT MEASURED PRIOR TO PLUGGING THE MEEKER WELL

LOADINGS

Salinity Parameter	Average Increase in Load October 1964 to June 1966[1]	Increase in Load October 1972[2]
Na	55 tons per day	21 tons per day
Cl	65 " " "	29 " " "
SO_4	80 " " "	24 " " "
TDS	280 " " "	89 " " "

CONCENTRATIONS

Salinity Parameter	White River Below Meeker Oct '64 thru Jul '68 (mg/l)		White River Below Meeker Aug '68 - Oct '71[3]		White River Upstream of Meeker - October '72 (mg/l)[4]
	(Average)	(Range)	(Average)	(Range)	(Average)
Na	52	19-88	19	6-29	18
Cl	61	18-100	15	4-26	22
SO_4	147	57-240	122	39-174	78
TDS	477	236-801	355	167-428	294

1) Calculated from 12 measurements: White River upstream of Coal Creek to White River "below" Meeker.
2) Calculated from 2 measurements: White River 0.4-km upstream of Coal Creek, and White River 2-km upstream of Meeker.
3) Bureau of Reclamation.
4) Upstream of Curtis Creek.

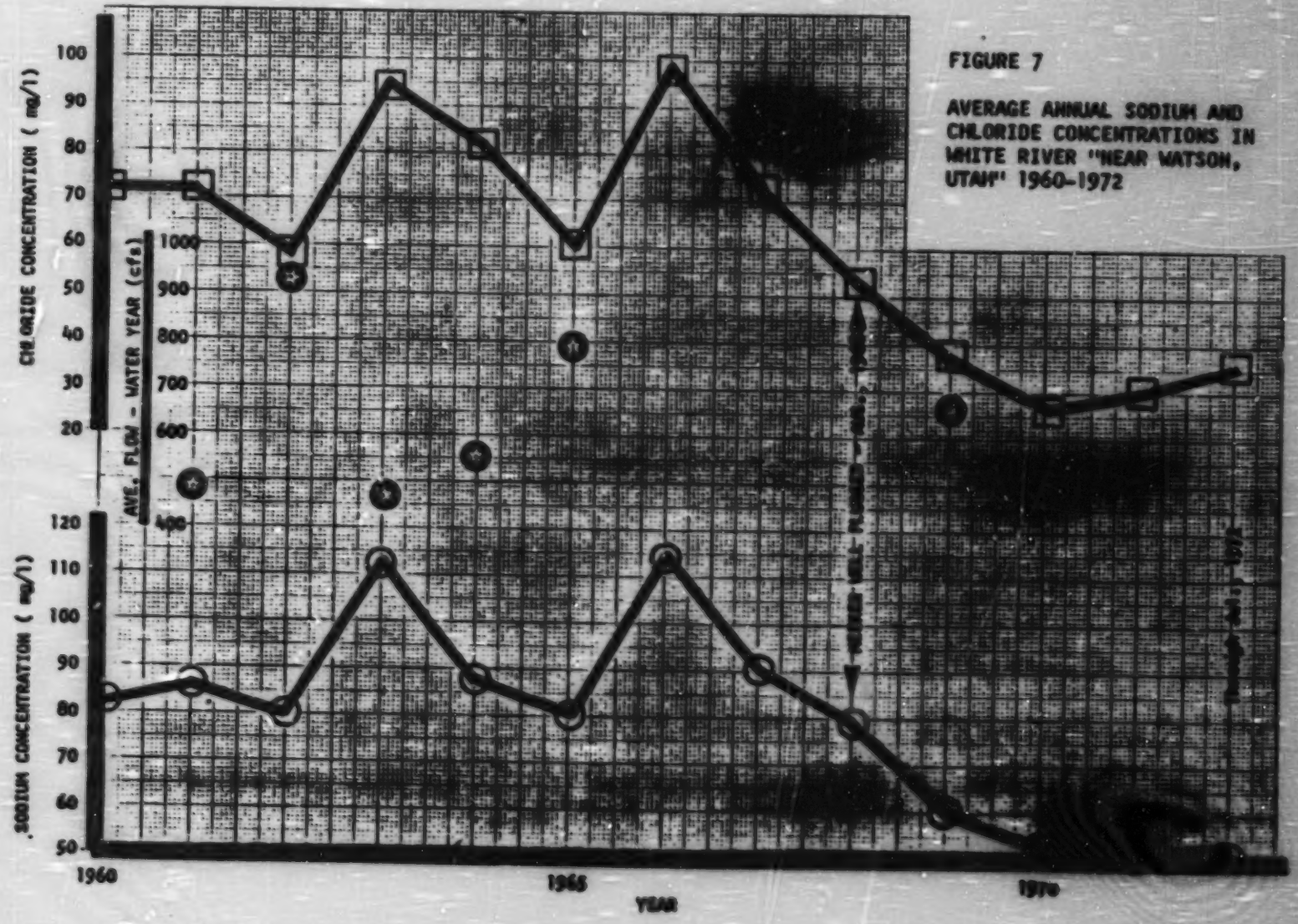


FIGURE 7

AVERAGE ANNUAL SODIUM AND CHLORIDE CONCENTRATIONS IN WHITE RIVER "NEAR WATSON, UTAH" 1960-1972

data, were/are gathered from downstream of Meeker. In other words, a further increase in salinity may be expected from the point of the October "downstream" collection to the long-term station "below" Meeker. However, we have assumed this downstream increase to be small when compared with the apparent differences in concentrations before and after plugging.

Comparison of sodium chloride, sulphate, and dissolved solids data reveals no discernable trend in the concentrations after the plugging of the Meeker Well. In other words, the data in our possession do not show an increase in salinity in the White River in the period following the plugging of the Meeker Well. As shown in Table 5, the data gathered in October of 1972 appear to fit within the range of previously measured (yet post-plugging) concentrations, recognizing that the October measurements were made during a period of relatively low flow.

Further comparison of sodium and chloride concentrations at a sampling location in the White River in Utah (some considerable distance downstream from Meeker) also fails to reveal any definitive increase in sodium or chloride since the "Meeker Well" was plugged (Figure 7.) We recognize the problems inherent in making such a comparison of concentrations especially when inadequate flow data are available.

We should also mention, as shown in Figure 5, that Coal Creek carries water with an appreciably-high specific conductance well upstream of Highway 132 and east of the field affected by the "eastermost" system. The Mancos Shale undoubtedly causes much of this "salinity."

Results of Reconnaissance Drainage Investigation on Upper Prather Property (Seepage Area #4)

The Bureau of Reclamation performed a reconnaissance drainage investigation in Sections 28 and 30, T1N, R93W, in late June of 1972 and reported on this investigation in September, 1972. (Enclosure to letter from Acting Regional Director, Bureau of Reclamation, Region 4, to John A. Green, Regional Administrator, EPA, Region VIII, dtd. 8Sep72).

The report covers the drilling of four hand-auger holes to depths of three to four meters and the analysis of water and soil. The purpose of the effort was to obtain information relative to the feasibility of draining and reclaiming the Prather tracts of land located south of Colorado Highway 132 and north of Coal Creek. It is reported that the soils encountered contained up to 3.28 percent dissolved solids. The report concludes that "draining and reclaiming the salt-affected portions of the Prather property would be rather

difficult, costly, and would involve complex measures necessary to restore the land to a productive status." The conclusion is based on the apparent complexity of the leaching and drain system envisioned to be necessary by the Bureau (a function of low permeabilities and deep (4m) "penetration" of salts). The estimated cost of installing a subsurface drain is $25,000.

The Bureau report projected an annual discharge (from the leaching process) to the White River of 110 tons of salt (T.D.S), annually. This compares with a calculated increase of 89 tons per day measured along the White River in October. The report also states that the water-bearing strata were encountered at depths between 4 and 6 feet (1.2 to 1.8 meters) in all four holes and that water in the two upslope holes showed a "slight" artesian rise." Conductance measurements of water encountered in these holes shows a decrease in salinity in the downslope direction (southward). (The four wells were located along an irregular vector leading generally south from Colorado Highway 132 toward Coal Creek - Figure 8). As has been suggested by the location of the seepage, the source of the saline seepage is to the north of the Prather field. It should also be pointed out that the two upslope holes encountered "appreciable amounts of raw shale fragments in the soil." This shale is most likely from the Mancos Formation and high salinity can be produced by seepage through these shales.

Summary

Essentially three divisions of field effort have been reported here. These are (1) the aerial infrared photography, (2) the measurement of specific electrical conductance and selected salinity parameters, and (3) the investigation of the feasibility of reclaiming the formerly-irrigated field currently degraded by saline ground water. All efforts were conducted in a cooperative manner with the Colorado Water Conservation Board, The Bureau of Reclamation, The Colorado Department of Health-Water Pollution Control Division, The U.S. Geological Survey, and EPA.

The infrared photography vividly portrays the land degradation in the eastern-most area of seepage, a formerly-irrigated field. The photography also shows significant seepage from the northern edge of the Meeker Dome near and downstream of an abandoned and plugged well (Kritsas #1). Equally detrimental seepage in other areas was not evident. It seems noteworthy that significant land degradation was not seen downslope from Coal Creek in the eastern-most area of seepage.

Measurements of salinity parameters in the vicinity of the Meeker Dome during October of 1972 indicated a daily pickup in load of dissolved solids of 89 tons per day along the reach of the White River from upstream of Coal Creek to upstream of (near) Curtis Creek.

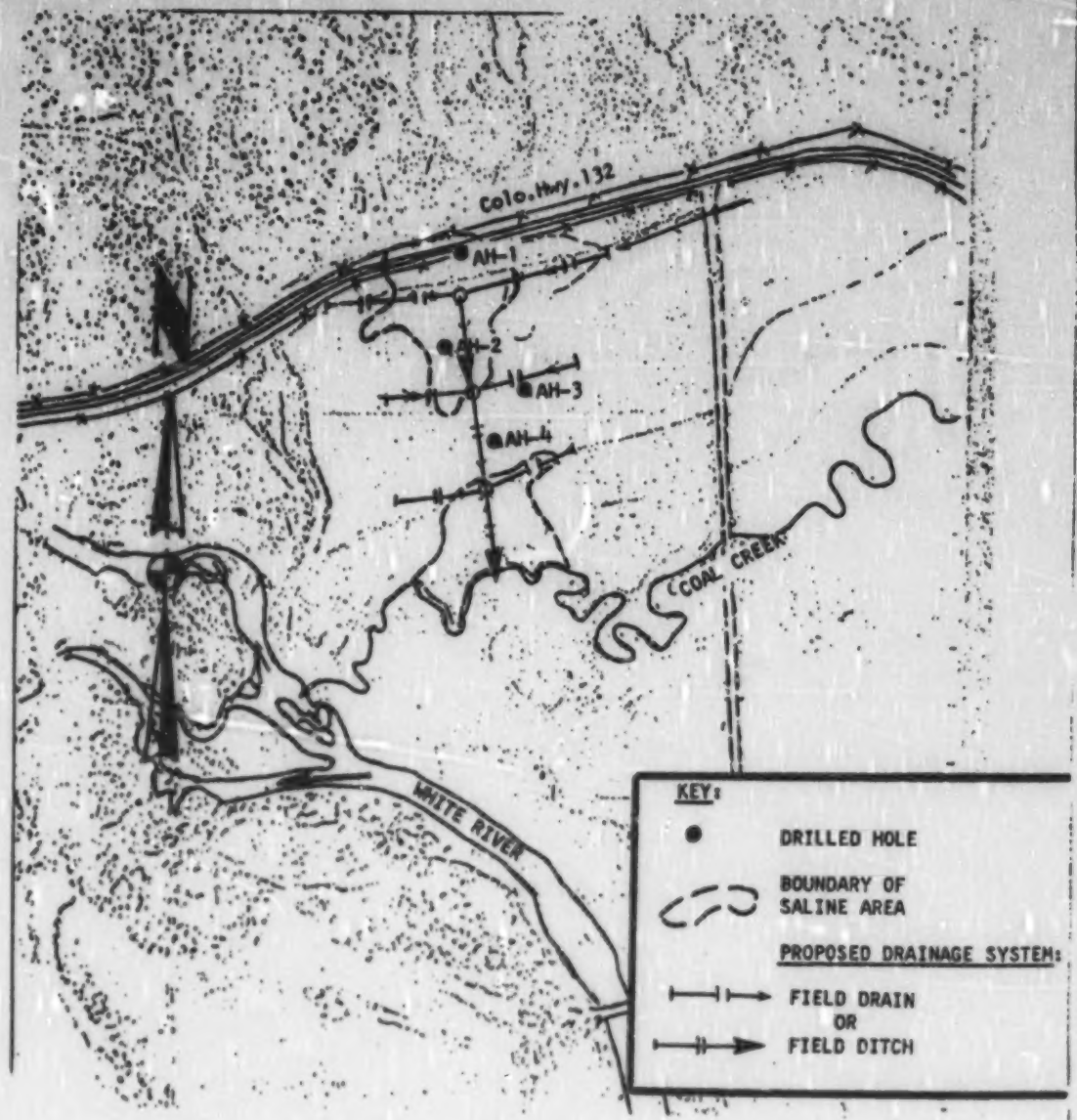


FIGURE 8

LOCATION OF AUGER HOLES AND POSSIBLE SUBSURFACE DRAIN - SEEPAGE AREA #4. after Bureau of Reclamation, 8Sep72

Sodium and chloride concentrations increased by 80 to 90 percent along the reach. The major contributor to this increase was Coal Creek, though high specific electrical conductance was also measured in irrigation return flows in flow from drainage ditches which included ground water seepage, and in Coal Creek upstream of known areas of seepage. Conductance was highest in Curtis Creek which drains the north and western portions of the Meeker Dome in addition to receiving a major portion of its drainage from the north (of the Meeker Dome).

The concentrations measured (Na, Cl, SO_4, TDS) for White River samples and flows recorded in October 1972 appeared to fit with other post- "Meeker Well" plugging measurements and to show no upward trend in salinity in the White River. However, the lack of long-term data makes this conclusion tenuous.

The results of the reclamation investigation did not indicate that it would be practicable to reclaim the field due to the necessary complexity of the leaching and drain system. However, the investigation report indicated that the ground water was found between 1.2 and 1.8 meters below the ground surface. The investigation did not cover the western-most seep, that affecting an irrigation canal and access road.

Field investigations by representatives of the U.S.G.S. and the Colorado Water Conservation Board have established the location of three other wells on the Dome, one of which (The Marland Well) is not plugged and has experienced a rise in water level. It has also been learned that saline, warm springs existed in the area prior to 1900.

Conclusions

The question of the Meeker Dome seepage has been related to what, if any, relationship exists between the "Meeker Well," as plugged, and the seepage of ground water. Based on the data at hand and the experience of the investigating parties, we conclude that the plugged "Meeker Well" has the same relationship to the seeps as do all other plugged wells in the area. That is, the plugging of all wells that intercepted aquifers has removed the artificial pressure relief channels formed by the unplugged wells such that naturally saline ground water is again under sufficient pressure to force it to the surface through natural fractures in a manner similar to that existing prior to the drilling. Replugging the wells will not achieve a reduction in seepage if these fractures intercept the aquifers as they appear to do.

It is possible, that certain wells, even in their "plugged" state serve to connect the deeper aquifers such as the Weber Formation, with shallower formations, such as the Morrison. In fact, a recently-drilled well (#1 Anderson-Dyco Petroleum) encountered water near the base of the Morrison in October of 1972 and in the Entrada Formation. Flows from about .14 cms to about 1.4 cms were encountered in the lower Morrison and Entrada. Water is not normally considered as present in any great quantity at the base of the Morrison though the Morrison has sufficient sands to make it an adequate aquifer if waters are available.

Recent salinity measurements show a pickup of salts through the area of seepage resulting in a pickup of sodium chloride, sulphate, and dissolved solids along the White River. But these increases appear to be substantially less than the increases occurring before plugging of the Meeker Well. An hypothesis has been advanced that the salinity increase may return the White River salinity level equal to that measured before plugging. Our single set of samples can not support this hypothesis since the post-plugging concentrations appear to be consistent after plugging and well below those measured prior to plugging.

While it appears feasible to reduce the impact of seepage on the irrigation ditch and access road at Seepage Area 1, the Bureau of Reclamation has reported that reclamation of the Seepage Area 4 and restoration to its pre-seepage condition would be difficult. While adequate exploration of this Area 4 to determine whether the seepage comes from below the field and percolates upward or whether the seepage originates from the vicinity of Colorado Highway 132 and percolates down-gradient has not been initiated, it does appear appropriate to conclude that the system is sufficiently complex so as to preclude additional extensive and expensive studies. We should keep in mind that the feasibility of intercepting seepage upstream of the Seepage Area 4 and constant flushing with "good" water has not been tested.

Finally, we conclude that further investigations, other than those listed below, are not warranted at this time.

Recommendations

The only recommendations of a technical nature considered appropriate at this time are the following:

(1) Selected salinity and flow data should be collected from two White River locations upstream and downstream of the drainage from the Meeker Dome for at least two years to determine whether or not the seepage will increase in either flow rate or salinity

parameter concentrations and thereby cause a deterioration in the quality of the White River.

(2) Plans should be developed to permit access to the irrigation ditch at Seepage Area 1.

(3) The Marland Well should be monitored routinely unless there is sufficient flow from this well to indicate the need to consider plugging.

(4) If monies are available for the drilling and completion of two holes, each about 30 meters deep and located upslope and downslope of Seepage Area 4, it may (consider the use of the word "may") be possible to determine whether water entering this Area comes from beneath the area or from above (upslope of) the area. EPA cannot presently identify any of its funds for this investigatory effort.

(5) In lieu of determining the exact flow system that directs local seepage in Area 4 (Upper Prather tract), changes in the extent and nature of the seepage should be recorded routinely.

(6) Certain factors relating to geologic instabilities of the south flank of the Meeker Dome should be brought to the attention of the Colorado Department of Natural Resources. The appropriate participants in this study may wish to do this quite soon if their observations are confirmed.